Joint Parallel Nuclear Alternatives Study for Russia

Final Report

Prepared For

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and
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EXECUTIVE SUMMARY

Introduction and Scope

The Joint Parallel Nuclear Alternatives Study for Russia (JPNAS) is a parallel study to the Joint Electric Power Alternative Study for Russia (JEPAS) The JPNAS assessed the costs of enhancing the safety level of Russian Nuclear Power Plants (NPPs), decommissioning of RBMK-1000 and first generation VVER-440 units, completion of NPP construction, NPP repowering into a fossil fuel plant, and construction of new generation NPPs In the framework of the Joint Energy Alternatives Study, the JPNAS provides data on the nuclear sector which is needed to formulate an integrated resources plan and schedule of investments for the development of Russia's power sector

The work of the JPNAS was undertaken by a team of Russian and American experts working in close cooperation

Current Status and Background

On January 1, 1994 there were 9 Nuclear Power Plants (NPPs) with 29 power units in Russia, their total installed capacity was about 21 GWe, or 10 6% of total installed capacity of the Russian power sector In 1993, Russian nuclear power plants produced some 118 trillion watt-hours (118 TWh) of electric energy

Power reactors in commercial operation were of several types

> RBMK-1000, a graphite moderated, pressure-tube, low enriched reactor rated at 1000 MWe, designed for on-line refueling (there are two generations of RBMK-1000 reactors that differ in some design features and physical parameters),
> VVER-440 (Models V-179 and V-230), a first generation pressurized water reactor rated at 440 MWe,
> VVER-440/213, a second generation pressurized water reactor also rated at 440 MWe, and
> VVER-1000, a second generation pressurized water reactor (of the V-187, V-338, and V-320 models) rated at 1000 MWe

In addition, a liquid metal-cooled fast reactor (BN-600) is connected to the Ural grid and four small (12 5 MWe) water-cooled graphite-moderated channel type (EGP-6) reactors operate isolated from the grid in the north of the far eastern portion of Russia

Fuel resources and the required infrastructure exist in Russia for supplying fuel to all existing nuclear power plants at current levels of consumption, now and for the foreseeable future Resources and infrastructure exist in Russia to support the production of most nuclear power plant components required for power plant completion, safety related upgrades, and new power plant construction

General Assumptions and Methodology

The work was structured on the assessment of six Options for the Russian nuclear sector which had been developed from the Terms of Reference (TOR), see Annex 1 They are as follows

Option 1	Provide safety upgrades to units with the RBMK-1000 and first generation VVER-440 reactors to allow operation until the end of service life at a safety level acceptable to the West
Option 2	Decommission units with the RBMK-1000 and first generation VVER-440 reactors
Option 3	Repower the partially completed Rostov-1, a VVER-1000 reactor, as a fossil fuel plant
Option 4	Complete the partially completed Kalinin-3, a VVER-1000 reactor, with safety upgrades to allow operation at a safety level comparable to the West
Option 5	Provide safety upgrades to operating units with the VVER-1000 and VVER-440/213 reactors to permit operation of these reactors at reduced levels of risk
Option 6	Build a new generation evolutionary power plant NP-500

For options that include safety upgrades (options 1,4, and 5), the JPNAS operationally defined, for the purposes of this study, a set of upgrades that raised the level of safety at the associated NPP's and that might be acceptable to potential investors

The cost estimates derived here were based on drawings and specifications for some specific upgrades and units and conceptual designs

Safety Upgrades

Programs for safety upgrades to all Russian reactors have been developed and are being implemented in Russia JPNAS experts have proposed a set of safety upgrades that would narrow the gap between the safety level of Russian reactors and the safety level acceptable to the West

In addition, it must be noted that safety is improved not only by equipment upgrades, but also by operational improvements Therefore, the Russian safety program includes steps aimed at improving operation and maintenance, quality control, diagnostic methods, administrative controls, personnel qualifications and training, and periodic safety assessments

One of the major objectives of the JPNAS was to estimate the cost of selected safety upgrades for Russian NPPs that increase the level of safety The set of upgrades included the following

A subset of the upgrades developed by the Russian engineers for the International Users Group (IUG) of Soviet Designed Reactors and published in a March 1994 report prepared for the World Association of Nuclear Operators (WANO) that includes all the upgrades directly associated with reactor and plant safety[1]

The implementation of confinement/containment systems for RBMK-1000 and first generation VVER-440s

Certain additional engineering studies from the current Russian program to identify upgrades not included in the two previous items Referred to hereafter as "upgrades beyond WANO"

The JPNAS evaluation of the containment systems for RBMK-1000 and first generation VVER-440 was included at the request of the US experts

For the purposes of this study, three confinement/containment systems were conceptually designed and costed These were

1) a US style containment system for RBMK-1000 and first generation VVER-440 reactors,

2) a jet condenser pressure suppression system and a metal confinement structure of Russian design over the operating floor for RBMK-1000,

3) a jet condenser pressure suppression system with some additional confinement elements for the first generation VVER-440 reactors

The construction of a U S style containment at either an RBMK-1000 or a first generation VVER-440 would be technically feasible but very costly

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[1] It should be noted that the major part (>85%) of the IUG-set are directly associated with reactor and plant safety

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Safety upgrades that have already been completed as part of the current Russian upgrade program have not been included in the JPNAS Prorated costs associated with completing safety upgrades that are currently in process were included in the study The status of the safety upgrades was determined during a series of meetings between JPNAS experts and the staff of Rosenergoatom Additional engineering studies and confinement/containment systems which are aimed at addressing safety issues not included in the current program are also included in the study

Decommissioning of Units with RBMK-1000 and First Generation VVER-440 Reactors

The JPNAS assessed the cost of decommissioning units with RBMK-1000 and first generation VVER-440 reactors The cost assessments for decommissioning included direct costs and social costs calculated in accordance with the Russian law Two approaches were considered a Russian approach and a U S approach Both approaches used the same data provided by Russian experts and used the same methods for the evaluation of social costs

Two decommissioning scenarios were considered for each decommissioning approach
- Planned - reactor is shutdown at the end of service life (EOSL)
- Early - reactor is shutdown 5 years prior to EOSL

The Russian and U S approaches to decommissioning are based on the maintenance, repair, and replacement experience in each country Thus, they reflect the decommissioning procedures that regulatory and utility organizations find acceptable in the respective countries This resulted in differences in the costs for the Russian Federation and U S approaches to decommissioning

It should be noted that neither approach can be claimed to be optimal An effort to find an optimal approach in either country might prove to be highly cost effective, see proposed project #2 below

Other Options

Repowering Rostov-1 as a coal fueled plant is more expensive than the alternative of completing this plant as a nuclear unit

Russia has developed several advanced NPP concepts with enhanced safety features in a program analogous to the US advanced reactor program Considered in this study is the 635 MWe NP-500

The NP-500 NPP project has a double protective containment shell, advanced passive safety systems, additional active safety systems and operational systems, important for safety, with enhanced reliability and redundancy The plant is of compact design leading to reduced material quantities and more effective space utilization Projected man-power requirements are substantially less than for operating Russian NPPs

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Results and Observations

The costs derived for each of the nuclear options are summarized in Tables ES-1 and ES-2 The costs in Table ES-1 are based on conditions that prevail in the U S Table ES-2 reflects Russian costs derived from the U S costs and based on conversion factors discussed in Section 4 The Russian costs were used in the JEPAS as input for the integrating model The differences between the tables result from the fact that there are significant differences in industrial practice, construction practice, labor productivities, and labor and material costs in our two countries Note that the US costs provided in table ES-1 could be used as a basis for developing nuclear option costs for other countries after the development of appropriate country specific conversion factors and appropriate technical information

The costs in the tables are presented as maximum and minimum estimates The maximum assessment for each option is the maximum cost of upgrade implementation among all units considered A similar definition is used for the minimum estimates

These costs are 1) overnight costs and, 2) include large contingency amounts ranging from 10 percent of the base construction cost (BCC) to upwards of 30 percent of BCC The term "overnight costs" signifies that the amount is simply the aggregate of all costs as if they were incurred at a single point in time

The JPNAS cost estimates cannot, by themselves, be used for determining the best nuclear options The estimates are derived primarily to provide data for integrating models

Proposed Nuclear Projects for Consideration

The JPNAS has identified several specific projects for early financing and implementation which would facilitate achieving the nuclear objectives delineated in the TOR They are

1) Development of the optimal implementation strategy for safety upgrades of operating NPP's

2) The development of a decommissioning program for a specific RBMK-1000 reactor

3) Completion of the design of the NP-500 and NP-1000 (new generation evolutionary reactors) to a sufficient level of detail so as to allow a full-scale licensing process

Table ES-1
"OVERNIGHT" BASE CONSTRUCTION COST ESTIMATE SUMMARY
U S CONDITIONS
(IN CONSTANT JANUARY 1 1994 DOLLARS)

Option Description			Project[1] Duration (Months)	Total Cost[2] High/Low (10^6 $)	Total Cost[2] High/Low ($/kWe)[3]
Option 1 Continuation	With Confinement and Jet Condenser	RBMK-1000 (1000 MWe)	24	224/87	224/87
		VVER-440/230 (440 MWe)	21	115/89	262/202
	With Full Containment	RBMK-1000 (1000 MWe)	36	649/429	402/87
		VVER-440/230 (440 MWe)	36	365/286	829/650
Option 2 Planned Decommissioning	Russian Approach	RBMK-1000 (1000 MWe)	516	1253/1185	1253/1185
		VVER-440/230 (440 MWe)	516	640/600	1455/1364
	U S Approach	RBMK-1000 (1000 MWe)	144	427/360	427/360
		VVER-440/230 (440 MWe)	120	332/292	755/664
Option 2 Early Decommissioning	Russian Approach	RBMK-1000 (1000 MWe)	480	1279/1212	1279/1212
		VVER-440/230 (440 MWe)	480	648/608	1473/1382
	U S Approach	RBMK-1000 (1000 MWe)	144	457/391	457/391
		VVER-440/230 (440 MWe)	120	776/685	136/22
Option 3 Conversion of a VVER-1000 to Organic Fuel(1500 MWe)[4]			24	1457	1457
Option 4 Completion/Upgrade of a VVER-1000 (1000 MWe)[4]			26	561	561
Option 5 Upgrade of a VVER-440 /213 (440 MWe)			21	50/40	114/91
Option 5 Upgrade of an Operating VVER-1000 (1000 MWe)			18	97/58	97/58
Option 6 New Generation NP-500 (635 MWe)			48	1455/1164	2291/1833

1 RBMK Project Duration 1 year shutdown for jet condenser/confinement 3 year shutdown for full containment Both include fuel channel replacement
VVER Project Duration 6 month shutdown for jet condenser/confinement 3 years for full containment
2 Base construction cost with owner s cost and contingency
3 Based on Gross Electric Capacity
4 Only one unit evaluated

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Table ES-2
"OVERNIGHT" BASE CONSTRUCTION COST ESTIMATE SUMMARY
RUSSIAN CONDITIONS
(IN CONSTANT JANUARY 1 1994 DOLLARS)

Option Description			Project[1] Duration (Months)	Total Cost[2]	
				High/Low (10^6 $)	High/Low ($/kWe)[3]
Option 1 Continuation	With Confinement and Jet Condenser	RBMK-1000 (1000 MWe)	24	90/35	90/35
		VVER-440/230 (440 MWe)	21	39/29	90/66
	With Full Containment	RBMK-1000 (1000 MWe)	36	228/136	228/136
		VVER-440/230 (440 MWe)	36	111/87	252/198
Option 2 Planned Decommissioning	Russian Approach	RBMK-1000 (1000 MWe)	516	198/169	198/169
		VVER-440/230 (440 MWe)	516	124/108	282/245
	U S Approach	RBMK-1000 (1000 MWe)	144	78/49	78/49
		VVER-440/230 (440 MWe)	120	64/48	145/108
Option 2 Early Decommissioning	Russian Approach	RBMK-1000 (1000 MWe)	480	200/172	200/172
		VVER-440/230 (440 MWe)	480	125/109	284/247
	U S Approach	RBMK-1000 (1000 MWe)	144	81/52	81/52
		VVER-440/230 (440 MWe)	120	65/49	147/110
Option 3 Conversion of a VVER-1000 to Organic Fuel(1500 MWe)[4]			24	557	371
Option 4 Completion/Upgrade of a VVER-1000 (1000 MWe)[4]			26	146	146
Option 5 Upgrade of a VVER-440 /213 (440 MWe)			21	14/11	32/25
Option 5 Upgrade of an Operating VVER-1000 (1000 MWe)			18	29/16	29/16
Option 6 New Generation NP-500 (635 MWe)			48	529/440	833/693

1 RBMK Project Duration — 1 year shutdown for jet condenser/confinement 3 year shutdown for full containment. Both include fuel channel replacement
VVER Project Duration — 6 month shutdown for jet condenser/confinement 3 years for full containment
2 Base construction cost with owner s cost and contingency
3 Based on Gross Electric Capacity
4 Only one unit evaluated

1.0 INTRODUCTION

1.1 BACKGROUND OF THE JOINT ELECTRIC POWER ALTERNATIVE STUDY (JEPAS)

At the July 1992 Munich G-7 Summit, the G-7 countries expressed their concern about the safety of certain Soviet-designed nuclear power plants (NPPs) and commissioned the World Bank and the International Energy Agency (IEA) to investigate replacement sources of electrical energy and their cost implications. The result, a report entitled "Russia Electricity Options", jointly drafted by the government of Russia, the World Bank, the IEA, and the European Bank for Reconstruction and Development was submitted to the G-7 in June 1993.

At the G-7 Tokyo Summit (July 1993), the participants urged the development of a framework for coordinated action among donor countries and multilateral financial institutions to assist Russia and other relevant countries with long-term energy planning to enable the earliest possible closure of their riskiest nuclear reactors.

On September 1 and 3, 1993, Prime Minister V. Chernomyrdin and Vice President A. Gore, meeting in the context of the U.S. - Russia Joint Commission on Economical and Technological Cooperation (JCTC), in keeping with the G-7 framework development effort, agreed on a joint effort to examine options for Russia's electrical energy future. This effort is the Joint Electric Power Alternative Study (JEPAS).

The main goal of the JEPAS is to provide a time phased investment program for the development of the Russian power sector for the period 1995-2010. An integrated resources plan provides the context for coordinating the schedule for new plant construction, for plant decommissioning, and for plant upgrades, so that forecast electrical demands will be met at all times at least cost. The data requirements of such a plan include those of the nuclear sector.

At the time of the second session of the JCTC on 16 December 1993, Prime Minister V. Chernomyrdin and Vice President A. Gore made a joint statement reaffirming the agreement of the two sides to carry out the above-mentioned study.

1.2 THE JOINT PARALLEL NUCLEAR ALTERNATIVES STUDY FOR RUSSIA (JPNAS)

The Joint Parallel Nuclear Alternatives Study for Russia (JPNAS) is a parallel study to the JEPAS. This study is aimed at the assessment of the costs of enhancing the safety level of Russian NPPs, decommissioning of units with the RBMK-1000 and first generation VVER-440 reactors, costs for the completion of NPP units under construction, repowering of NPPs as fossil fuel plants, and the construction of new generation NPPs.

In the framework of the Joint Energy Alternative Study, the JPNAS is to provide data on the nuclear sector which are needed for use in the integrated resource planning models being used to analyze investment options for the Russian Power Sector This JPNAS Final Report is based on the Interim Report which was submitted to the JCTC in July 1994

The implementation of the JPNAS was based on the Terms of Reference (TOR) which were agreed to by the U S Department of State (DOS) and the Ministry on Atomic Energy of the Russian Federation (MINATOM) Overall coordination of U S activities was provided by DOS Important to the success of the joint effort was the support and guidance provided by the United States Department of Energy (DOE) A parallel role was played by MINATOM In addition to providing guidance to the JPNAS, MINATOM staff provided necessary data and actively participated in report preparation and review

Table 1-1 The Objectives for the JPNAS from the JEPAS Terms of Reference

A	*Should the decision be taken to shut down first generation reactors, analyze the economic and practical consequences of such a possible decision, especially an assessment of the costs directly associated with the decommissioning of operating nuclear power plants, but also the economic and social consequences to the nuclear work force*
B	*Assess the consequences and costs of converting partly-built nuclear power plant construction sites that were never completed into power stations that use fossil fuel*
C	*Determine the costs of utilizing partly-completed nuclear power plants to replace old reactor units, including safety-related upgrades necessary to achieve a level of safety comparable to the West, additional construction costs, plant operation and fuel costs, and impacts on energy infrastructure*
D	*Take into account Russian plans for new nuclear generation, including new nuclear power plant designs adapted from current designs, and their anticipated costs*
E	*Take into account Russian plans for upgrading existing nuclear power plants and their anticipated costs*
F	*Take into account cost of continued operation of first generation VVER and all RBMK reactors to the end of their lifetimes with upgrades to standards acceptable to the West*

On the basis of these six objectives, the JPNAS developed specific options which are discussed in detail in Section 3 The objective of JPNAS is to evaluate costs and time requirements for the objectives above

Specifically, the JPNAS is to prepare the estimates of capital costs for reactor safety upgrades to existing reactors and for new nuclear power plants, fuel and non-fuel operating and maintenance costs for all nuclear power plants, and decommissioning costs including social costs for plants to be

retired during the study period
With these data and similar data for the other alternatives it is possible to develop the recommendations of the optimal development of the Russian power sector in the framework of an integrating economic model

1 3 THE JOINT EFFORT OF MINATOM OF THE RUSSIAN FEDERATION AND THE U S DEPARTMENT OF ENERGY

The U S Department of Energy invited the Brookhaven National Laboratory to undertake the study of the Russian nuclear power sector in support of the JEPAS Such a study could only be feasible with the whole-hearted cooperation of MINATOM of the Russian Federation which holds through its subordinate agencies and institutes the design and operating data of Russian reactors needed for the JPNAS In addition to providing these data, its personnel brought to the project an understanding of the infrastructure and social context of the nuclear power sector and of important safety issues involved in the operation of Russian reactors The knowledge and experience of the Russian reactor operators and developers have played an important part in the development of this report and its cost estimates

The work of the JPNAS was undertaken by a team of American and Russian experts working in close cooperation The Russian team members were affiliated with the organizations within the structure of the Ministry on Atomic Energy of the Russian Federation including Rosenergoatom (Russian Utility Company), AtomEnergoProekt (VVER and RBMK architect engineers), the St Petersburg AtomEnergoProject (Head designer of the VVER 640 NPP Project), GYDROPRESS (a VVER reactor vendor), VNIIAES (an Institute for nuclear plant operations), and some other organizations On the Russian side the project was coordinated by the experts of the Russian Research Center "Kurchatov Institute" For the U S side, at the request of the U S Department of Energy, the project was coordinated by the Brookhaven National Laboratory The work was performed at the Kurchatov Institute in Moscow, Russia, the Brookhaven National Laboratory, New York U S , and Raytheon Engineers and Constructors, Philadelphia, USA

During the preparation of the JPNAS Final Report, additional Russian data were received and the cost assessments and underlying assumptions of the Interim Report were examined and revised In addition, data on individual units were received and used to arrive at cost assessments on a per reactor basis as opposed to the representative reactor basis of cost assessments in the Interim Report

The close working relationship between Russian and American experts established during the course of the JPNAS accompanied by the exchange of viewpoints and ideas may be expected to be valuable to both countries for further development of their electric energy sectors

1 4 ORGANIZATION OF THE REPORT

In Sectıon 2, the current status of the nuclear power sector of Russıa ıs bnefly descnbed Avaılable nuclear power plants are lısted along wıth the power pools wıth whıch they are assocıated, theır reactor model desıgnatıons, theır age, and safety status characterızed by the Russıan regulatory requırements to whıch they were desıgned and buılt In addıtıon, the contnbutıon of each ın terms of capacıty and electnc energy productıon to vanous regıonal gnds ıs provıded

In Sectıon 3, the sıx nuclear energy optıons, examıned ın the JPNAS, are descnbed

The methodology employed ın ıdentıfyıng safety upgrades to reactors of vanous desıgns ıs addressed ın Sectıons 3 and 4 In addıtıon, the approach to estımatıng the costs of ımplementıng the optıons are addressed ın Sectıon 4 It ıs ımportant to note that the safety upgrades are based on the recommendatıons for the Internatıonal Users Group of Sovıet Desıgned Reactors (IUG) developed by Russıan engıneers and publıshed by the World Assocıatıon of Nuclear Operators (WANO), plus some addıtıonal safety upgrades ıncludıng confinement and contaınment systems

Observatıons based on the analysıs of the optıons are presented ın Sectıon 5 The data upon whıch these observatıons are made, ı e , cost estımates, were denved for use ın an ıntegratıng model rather than for purposes of companson These estımates are provıded ın Tables 6-1, 6-2, and 6-3 as well as Annex #3 Only wıth extreme care can such estımates be used dırectly ın makıng compansons between optıons

In Sectıon 6, the findıngs of the JPNAS are revıewed and projects for future development are ıdentıfied

Annexes to the JPNAS Fınal Report are as follows

<u>Annex 1</u> Terms of Reference

<u>Annex 2</u> Basıc Assumptıons on Nuclear Fuel Pnces Thıs contaıns the basıc assumptıons for nuclear fuel pnces and alternatıve scenarıos for these pnces to be used ın an ıntegratıng model

<u>Annex 3</u> Cost Estımate Summary Tables Thıs contaıns the maın results of JPNAS ın tabular form

In addıtıon, the followıng appendıces have been prepared

<u>Appendıx A</u> contaıns the detaıls of the cost estımatıng methodology dıscussed ın Sectıon 4 [Raytheon's Energy Economıc Data Base (EEDB)]

Appendix B contains the safety upgrades to various reactors designs, repowering of existing partially completed nuclear plants to fossil fuel, completion of partially completed and construction of new evolutionary nuclear plants

Appendix C contains the Russian and U S approaches to decommissioning nuclear units

Appendix D contains a Glossary of Acronyms and Abbreviations

Appendix E contains the List of References

Appendix F contains a tabulation of EEDB data entry sheets and decommissioning scheduling and activities listings

Appendix G contains supporting 1994 WANO Reports

Appendix H contains analytical information regarding the current and future place of nuclear energy in Russia This paper was prepared by Russian experts

Appendix I contains the complete data set forwarded to the JEPAS for use in the integrating models

Appendix J contains information describing the current nuclear regulatory environment in Russia

Annexes 1, 2, and 3 are part of this Report Appendices A-J are issued as separate volumes

2 0 CURRENT SITUATION

2 1 CURRENT STATUS OF THE RUSSIAN NUCLEAR POWER SECTOR

On January 1, 1994 there were 9 Nuclear Power Plants (NPPs) with 29 power units in Russia, their total installed capacity was 21 242 GW(e), or 10 6% of total installed capacity of the Russian power sector In 1993, Russian nuclear power plants produced some 118 trillion watt-hours (118 TWh) of electric energy

Several types of power reactors are in commercial operation

- RBMK-1000, a graphite moderated, pressure-tube, low enriched reactor rated at 1000 MWe, designed for on-line refueling (there are two generations of RBMK-1000 reactors that differ in some design features and physical parameters),
- VVER-440 (Models V-179 and V-230), a first generation pressurized water reactor rated at 440 MWe,
- VVER-440/213, a second generation pressurized water reactor also rated at 440 MWe, and
- VVER-1000, a second generation pressurized water reactor (of the V-187, V-338, and V-320 models) rated at 1000 MWe

In addition, a liquid metal-cooled fast reactor (BN-600) is connected to the Ural grid and four small (12 5 MWe) water-cooled graphite-moderated channel type reactors (EGP-6) operate isolated from the grid in the north of the far eastern portion of Russia

Of the 29 operating units, there are

- 13 light-water reactor units of the VVER (PWR) type,
- 15 channel-type graphite moderated reactor units of the RBMK (LWGR) and EGP types,
- 1 fast reactor unit of the BN (LMFBR) type

The breakdown of total installed capacity by reactor type is given in Table 2-1

Nuclear power is one of the major electricity sources in the country In 1993, the share of nuclear electricity in total electricity generation was about 12 7% However, the importance of nuclear power greatly varies from region to region For example, in the regions with the most developed nuclear power - the North-West, Central and Middle Volga power pools - nuclear shares were, in

1993, 47 8%, 23 9% and 16 4% respectively

The current status of nuclear power plants is illustrated in Table 2-2, the typical capacity factors for Russian NPPs are given in Table 2-3 In addition to the commissioned plants, the following units are under construction

- Balakovo - units 5 and 6 (VVER-1000's),
- Kalinin - unit 3 (VVER-1000),
- Rostov - units 1, 2 and 3 (VVER-1000's),
- Kursk - unit 5 (RBMK-1000)

2 2 NUCLEAR FUEL SUPPLY

There are several categories of nuclear materials available for fuel in Russia They include

- Uranium in deposits
- Natural and enriched uranium in stocks
- Depleted uranium as a by-product of the enrichment process
- Uranium and plutonium from spent nuclear fuel
- Plutonium and highly enriched uranium from nuclear weapons

At present, only limited data on the quantities of these resources are available The 1993 report of an OECD NEA and IAEA study[1] assesses the quantity of uranium in deposits in Russia as ~445 thousand tonnes (the study considered only the RAR, EAR-I and EAR-II resource categories[2]) According to the current Russian Nuclear Program[3], the quantity of uranium in stocks can be assessed as ~275 thousand tonnes for a total of ~720 thousand tonnes of natural uranium in deposits and stocks

The same OECD NEA and IAEA study assessed the annual consumption of uranium for electricity generation in Russia as 4,000 tonnes/year Thus, at the present rate of consumption Russia has resources for the foreseeable future One can assume that with the addition of other nuclear resources and less certain categories of uranium deposits, this number can become even greater The assessment of the resources for nuclear fuel in Russia is summarized in Table 2-4

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1 Uranium 1993 Resources Production and Demand A Joint Report by the OECD Nuclear Energy Agency and the International Atomic Energy Agency Chapter on the Russian Federation

2 RAR = Reasonably assured resources EAR = Estimated additional resources both definitions are as assumed by the referred organizations in their studies

3 Development of the Strategy of the Development of Nuclear Power in the Framework of the Long term Integrated State Fuel-Energy Program The Energy Strategy of Russia of the Russian Federation for the Period up to 2010 Phase Development of the Project of the Nuclear Power Strategy in Russia MINATOMENERGO RF TsNIIATOMInform No 378/0 Moscow 1993 - in Russian

2 3 CURRENT STATUS OF THE IMPLEMENTATION OF SAFETY UPGRADES

Following the Chernobyl accident additional measures for increasing the reliability and safety of Russian reactors were identified as a result of safety analyses Some of these measures have been implemented, others are in the process of implementation Among those already implemented, the most important are the following

- VVER's
  - Upgrades focusing on ensuring the integrity of the primary circuit

- RBMK-1000's
  - A decrease in the positive void reactivity coefficient
  - The time to scram the reactor has been significantly decreased by the installation of an additional new scram system which has the capability of scramming the reactor independently of the scram system as originally designed
  - An increase in the sensitivity of the design scram system
  - The design of the control rods was changed so as to eliminate the possibility of an input of positive reactivity for any mode of reactor operation
  - Reactor operating regimes that could lead to extensive void formation were excluded
  - Upgrades focusing on ensuring the integrity of the primary circuit

The following safety upgrades are in the process of implementation for both VVER and RBMK's

- Organizational and technical measures aimed at increasing unit operational safety improvement of maintenance procedures, re-training of operators, installation of simulators, etc
- Measures to increase reactor plant reliability including the reliability of safety systems
- Installation of new diagnostic systems supporting various safety functions
- Improvements in the level of protection against fire and hydrogen explosions
- Enhanced seismic resistance
- Improved radiation safety directed toward reducing radiation exposure of plant workers, the general public and the environment
- Improvement in the storage of radioactive wastes and spent fuel
- Improved physical protection

Implementation of safety upgrades at operating nuclear units is performed sequentially on the basis of specific projects

One of the main advantages of the incremental approach is that a large amount of preparation for upgrades can be performed during unit operation and the final implementation of the upgrades can be incorporated into planned outages Another advantage of the incremental approach is that a substantial portion of these activities can be performed by plant personnel, minimizing the need for additional personnel and infrastructure In the case of RBMK-1000, upgrades which cannot be performed during planned outages are scheduled for periods of planned fuel channel replacement For VVER-440, upgrade activities requiring unit shutdown are scheduled for major overhaul periods

Among the organizational and technical measures the most important was the introduction in 1990 of the special operating regime for units with the RBMK-1000 and first generation VVER-440 reactors This regime includes the expansion of the surveillance of the integrity of the primary circuit, annual reassessment of safety of each unit under this regime with a report to the Russian regulatory authorities upon which authorization for continued operation is based In addition, other organizational and technical measures have been implemented If necessary, changes/exceptions to the approved special operating regime may be introduced, provided that the approval of the Russian regulatory authority (GAN) is granted

2 4 NEW RUSSIAN NPP DESIGNS

Russia has developed several advanced NPP concepts with enhanced safety features in a program analogous to the US advanced reactor program (considered in this study is the 635 MWe NP-500[4]) These innovative concepts, including the 1000 MWt NP-1000[5], provide a technological basis for expansion of nuclear power generation in Russia and for penetration of foreign markets by Russian technology In the absence of appropriate organizational and financial support final design and licensing of these projects may be delayed

2 5 FACTORS IN FUTURE NUCLEAR SECTOR DEVELOPMENT

Other factors that have a significant bearing on the role of nuclear sector development in Russia's energy future are

Energy Security The Diversification of the Energy Supply

The existence of a nuclear sector provides a strong measure of protection against events that might threaten the availability and costs of fossil fuel supplies

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4 Since December 1994 this project has been designated the VVER-640 however in this report, the old designation (NP 500) is used

5 Because of financial and schedule constraints the NP-1000 is not included in this Study

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Environmental Considerations

In evaluating various approaches to generation capacity expansion in the Russian Federation, impacts on the environment must be considered For example, nuclear power does not produce the atmospheric emissions associated with fossil fuel plants, but it does produce high level nuclear wastes that require long term storage and there is some risk posed by accidents These and other factors are difficult to quantify and were not included in the analyses They are an important element necessary to determine what generation expansion options are needed

Infrastructure

Resources and infrastructure exist in Russia to support the production of most nuclear plant components required for power plant completion, safety related upgrades, and new plant construction

Reactor Safety

The upgrades addressed in the JPNAS are designed to substantially increase the level of safety of Russian reactors The implementation of such upgrades is likely to increase acceptance of nuclear power in Russia by the public and by the international community

Table 2-1 Structure of the Russian Nuclear Power Sector on January 1, 1994

Reactor Type	Number of Units	Share in Total Capacity, %
RBMK-1000	11	51 8
VVER-1000	7	33 0
VVER-440	6	12 2
BN-600	1	2 8
EGP-6	4	0 2

Table 2-2 Nuclear Power Plants in Russia (Status of January 1, 1994)

No	NPP Denomination	Power Pool	Units	Reactor Type	Project Code	Capacity (gross) MWe	Safety Generation	Safety Regulation Basis	Year of Start up	Planned Shutdown Date
1	Balakovo	Middle Volga	1	VVER 1000	V-320	1000	2	OPB-73 - OPB 82	1985	2015
			2	VVER 1000	V 320	1000	2	OPB 73 - OPB 82	1987	2017
			3	VVER 1000	V 320	1000	2	OPB-73 - OPB 82	1988	2018
			4	VVER 1000	V 320	1000	2	OPB 73 - OPB 82	1993	2023
2	Beloyarskaya	Ural	1	AMB 100		100	1	Before OPB-73/OPB-82	1963	shutdown in 1980
			2	AMB 160		160	1	Before OPB-73/OPB 82	1967	shutdown in 1989
			3	BN 600		600	1	Before OPB-73/OPB 82	1980	2010
3	Bilibino	Isolated	1	EGP 6	-	12	1	Before OPB-73/OPB-82	1974	2004
			2	EGP 6		12	1	Before OPB 73/OPB 82	1974	2004
			3	EGP 6		12	1	Before OPB-73/OPB 82	1975	2005
			4	EGP 6		12	1	Before OPB 73/OPB-82	1976	2006
4	Kalinin	Center	1	VVER 1000	V 338	1000	2	OPB 73 - OPB 82	1984	2014
			2	VVER 1000	V 338	1000	2	OPB 73 - OPB 82	1986	2016
5	Kola	Northwest	1	VVER 440	V 230	440	1	Before OPB 73/OPB-82	1973	2003
			2	VVER 440	V 230	440	1	Before OPB-73/OPB 82	1974	2004
			3	VVER 440	V 213	440	2	OPB-73 - OPB 82	1981	2011
			4	VVER 440	V 213	440	2	OPB-73 - OPB 82	1984	2014
6	Kursk	Center	1	RBMK 1000		1000	1	Before OPB 73/OPB 82	1976	2006
			2	RBMK 1000		1000	1	Before OPB 73/OPB-82	1978	2008
			3	RBMK 1000		1000	2	OPB 73 - OPB 82	1983	2013
			4	RBMK 1000	-	1000	2	OPB 73 - OPB 82	1985	2015
7	Leningrad	Northwest	1	RBMK-1000		1000	1	Before OPB 73/OPB-82	1973	2003
			2	RBMK 1000		1000	1	Before OPB-73/OPB 82	1975	2005
			3	RBMK 1000		1000	2	OPB-73 - OPB 82	1979	2009
			4	RBMK 1000		1000	2	OPB 73 - OPB 82	1981	2011
8	Novovoronezh	Center	1	VVER 213		210	1	Before OPB-73/OPB-82	1964	shutdown in 1984
			2	VVER-365		365	1	Before OPB 73/OPB 82	1970	shutdown in 1990
			3	VVER 440	V 179	417	1	Before OPB-73/OPB-82	1971	2001
			4	VVER 440	V 179	417	1	Before OPB 73/OPB 82	1972	2002
			5	VVER 1000	V-187	1000	2	OPB-73 - OPB 82	1980	2010
9	Smolensk	Center	1	RBMK 1000		1000	2	OPB 73 - OPB 82	1982	2012
			2	RBMK 1000		1000	2	OPB-73 - OPB 82	1985	2015
			3	RBMK 1000		1000	2	OPB 73 - OPB 82	1990	2020

Table 2-3 Capacity and Operation Time Factors for Russian NPPs in 1993

No	NPP Denomination	Power Pool	Units	Reactor Type	Project Code	Capacity (gross) MWe	Capacity Factor in 1993 %	Operation Time Factor in 1993 %
1	Balakovo	Middle Volga	1	VVER 1000	V 320	1000	40	47
			2	VVER 1000	V 320	1000	45	47
			3	VVER 1000	V 320	1000	54	62
			4*	VVER 1000	V 320	1000	50	90
			Total			4000	65	62
2	Beloyarskaya	Ural	3	BN 600		600	80	81
3	Bilibino	Isolated	1	EGP 6		12	61	85
			2	EGP 6		12	60	81
			3	EGP 6		12	62	82
			4	EGP 6		12	75	79
			Total			48	61	82
4	Kalinin	Center	1	VVER 1000	V 338	1000	65	67
			2	VVER 1000	V 338	1000	59	79
			Total			2000	70	73
5	Kola	Northwest	1	VVER 440	V 230	440	56	64
			2	VVER 440	V 230	440	61	73
			3	VVER 440	V 213	440	71	78
			4	VVER 440	V 213	440	79	94
			Total			1760	67	77
6	Kursk	Center	1	RBMK 1000		1000	57	93
			2	RBMK 1000		1000	57	84
			3	RBMK 1000		1000	70	74
			4	RBMK 1000		1000	71	75
			Total			4000	64	81
7	Leningrad	Northwest	1	RBMK 1000		1000	81	84
			2	RBMK 1000		1000		
			3	RBMK 1000		1000	89	91
			4	RBMK 1000		1000	84	89
			Total			4000	64	66
8	Novovoronezh	Center	3	VVER 440	V 179	417	51	67
			4	VVER 440	V 179	417	74	82
			5	VVER 1000	V 187	1000	72	85
			Total			1834	69	78
9	Smolensk	Center	1	RBMK 1000		1000	78	80
			2	RBMK 1000		1000	82	86
			3	RBMK 1000		1000	83	85
			Total			3000	81	83
	TOTAL					21242	67	76

* Balakovo-4 was commissioned in December, 1993, full power was reached at the beginning of 1994

3 0 ASSESSED NUCLEAR OPTIONS

3 1 INTRODUCTION

The work was structured on the assessment of six Options for the Russian nuclear sector which had been developed from the Terms of Reference (TOR), see Annex 1 They are as follows

Option 1	Provide safety upgrades to units with the RBMK-1000 and first generation VVER-440 reactors to allow operation until the end of service life at a safety level acceptable to the West
Option 2	Decommission units with the RBMK-1000 and first generation VVER-440 reactors
Option 3	Repower the partially completed Rostov-1, a VVER-1000 reactor, as a fossil fuel plant
Option 4	Complete the partially completed Kalinin-3, a VVER-1000 reactor, with safety upgrades to allow operation at a safety level comparable to the West
Option 5	Provide safety upgrades to operating units with the VVER-1000 and VVER-440/213 reactors to permit operation of these reactors at reduced levels of risk
Option 6	Build a new generation evolutionary power plant NP-500

For options that include safety upgrades (options 1,4, and 5), the JPNAS operationally defined, for the purposes of this study, a set of upgrades that raised the level of safety at the associated NPP's and that might be acceptable to potential investors

One of the major objectives of the JPNAS was to estimate the cost of selected safety upgrades for Russian NPPs that increase the level of safety The set of upgrades included the following

- A subset of the upgrades developed by the Russian engineers for the International Users Group (IUG) of Soviet Designed Reactors and published in a March 1994 report prepared for the World Association of Nuclear Operators (WANO) that includes all the upgrades directly associated with reactor and plant safety[1]

[1] It should be noted that the major part (>85%) of the IUG set are directly associated with reactor and plant safety

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- The implementation of confinement/containment systems for RBMK-1000 and first generation VVER-440s

- Certain additional engineering studies from the current Russian program to identify upgrades not included in the two previous items Referred to hereafter as "upgrades beyond WANO" (considered in more detail in section 4 1 2)

The major measures for the safety enhancements of these nuclear power plants have been categorized on the basis of the specific plant elements which they address

- Integrity of the primary loop
- Reduction of control transients
- Integrity of the containment/confinement
- Protection from fires
- Accident management
- Methods, studies, and procedures

In the paragraphs which follow, the six options mentioned above are described in more detail Note that no attempt is made to compare one option with another Such comparisons can only be made in the context of the results of the integrating model for the power sector

3 2 SAFETY UPGRADES TO RBMK's AND FIRST-GENERATION VVER-440 REACTORS

The minimal upgrades for the RBMK-1000 and first generation VVER-440 reactors are specified in the WANO Reports entitled "Improvement of RBMK-1000 Nuclear Power Plant Safety" and "Improvement of VVER-440/230 Nuclear Power Plant Safety" published in March 1994, in particular, in Chapter 3 of these reports "Major Measures on Safety Enhancement to be Implemented in the Future" This report describes major tasks that would enhance the safety of the RBMK-1000 and first generation VVER-440 reactor units These tasks are described in Appendices B and G

For units with RBMK-1000 reactors, these tasks include replacement of fuel channels as discussed in Chapter 2 of the WANO report The Russian operators of these reactors consider RBMK fuel channel replacement to be planned maintenance (equipment replacement) and not strictly a safety upgrade

At the request of the U S experts containment systems were evaluated in the JPNAS They are discussed more fully in Section 4 1 3

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3 3 DECOMMISSIONING OF RBMK-1000 AND FIRST GENERATION VVER-440/230 REACTORS

Two approaches, referred to as the Russian approach and the U S approach, were considered for this option Both approaches used technical data provided by Russian experts

The Russian approach to the decommissioning process formed the estimating basis for the JEPAS This approach assumes a long-term safe storage of the plant until the time of final dismantling

The Russian approach is based on Russian studies tempered by maintenance, repair, and replacement experience As such, it reflects decommissioning procedures that regulatory and utility organizations find acceptable in the Russian Federation today

The specifics of the approach to decommissioning in Russia lie with the current GAN decision which states that the unit is considered to be in operation as long as spent fuel remains at the unit In the absence of detailed regulatory guidance, it was assumed that the unit operational staffing is maintained for the time between unit shutdown and the beginning of decommissioning An allowance for social costs, in accordance with Russian laws and practice, was included into the decommissioning costs

The U S approach was included in this study at the request of the U S experts This approach is based on a process of decommissioning characterized by immediate full plant dismantling

The U S approach is based on the results of U S studies tempered by the evolutionary effects of actual experience As such, it reflects decommissioning procedures that regulatory and utility organizations find acceptable in the U S today Social costs of decommissioning were assessed in the same way for both the U S and Russian approach

The U S approach to decommissioning Russian nuclear power plants was developed as a hypothetical case, on the basis of nuclear regulation, financial conditions and the technology base existing in the U S This resulted in differences between the costs of Russian and U S approaches to decommissioning However, there are large technical uncertainties for both approaches, for example, the handling of the irradiated graphite from RBMK's The impact of such uncertainties, in terms of cost and durations, is different for the US and Russian approaches Therefore, direct quantitative comparison of the respective overall cost estimates is not justified and neither approach can clam to be optimal However, the US approach was used as a change case in the system analysis to test for the sensitivity to decommissioning costs

3 4 REPOWERING ROSTOV-1 AS A COAL FIRED PLANT

The Rostov site was selected by the JPNAS experts as a representative repowering site for the purposes of this study The Rostov site was initially planned as a four-unit VVER-1000 NPP, however, the plant construction has been discontinued Unit 1 is approximately 95 percent complete, while Units 2, 3, and 4 are only about fifty, ten, and five percent complete respectively The site, installed systems and equipment have been maintained by the plant staff since construction at the plant was halted

The assessment of repowering Rostov-1 as a coal fired plant was premised on the maximum use of the equipment already installed The basic concept involves producing supercritical steam in fossil fueled boilers to drive additional high pressure topping turbines The exhaust steam flow from this system is cooled so as to match inlet conditions of the turbine of the partially completed nuclear unit The combined output of the generators driven by the topping turbines and those driven by the turbine of the partially completed nuclear plant is approximately 1500 MWe Thus, the repowered plant provides a total generating capacity of approximately 150 percent of the VVER-1000

To implement the repowering, substantial development of fossil fuel resources and railroad capacity would be required In the case of coal, this would include site development for coal storage and ash disposal The JPNAS has not estimated the costs associated with this infrastructure development

3 5 COMPLETION OF THE KALININ-3 VVER-1000

This option involves completing the construction of Kalinin-3, a VVER-1000/320 plant, which is reportedly 75 percent complete It is assumed that construction will be restarted after a period of inactivity This period of inactivity was assumed to be at least two years in duration, long enough to require some rework of certain plant systems and structures It is anticipated that the plant could be completed with sufficient safety upgrades to permit operation at reduced levels of risk

3 6 SAFETY UPGRADES TO OPERATING PLANTS WITH VVER-1000 AND VVER-440/213 REACTORS

These safety upgrades involve the modification of operating VVER-1000 and VVER-440/213 reactors so that they may operate at a reduced level of risk Recommendations of the following IUG reports constitute the basic set of upgrades 1) "Improvements of VVER-1000 Nuclear Power Plant Safety", dated March 1994, and 2) "Improvements of VVER-440/213 Nuclear Power Plant Safety", dated March 1994

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3 7 NEW EVOLUTIONARY NUCLEAR POWER PLANT NP-500

The NP-500 is one of Russia's evolutionary nuclear power plants with a medium power reactor rated at 1800 MWt and a gross output of 635 Mwe The NP-500 is being designed to have a higher level of safety than nuclear power plants currently operating in the Russian Federation This is achieved by applying passive safety systems and providing a double protective containment shell These features are claimed by the designers to decrease the probability of severe accidents by 2 to 3 orders of magnitude in comparison with operating nuclear power plants, such as the VVER-440/213 and the VVER-1000

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4.0 METHODOLOGY

4 1 REACTOR SAFETY

This section discusses the approach taken to identify, for cost estimating purposes, those safety upgrades required so that specified Soviet designed reactors may be operated at increased levels of safety

4 1 1 Safety Upgrades Beyond WANO

Additional safety upgrades beyond WANO considered by Russian and American experts were assessed. A majority of them are presently included in Russian plans for safety upgrades Some are currently being implemented at various NPPs

- Upgrades to cope with "Station Blackout"
- Provisions to safely manage Anticipated Transients Without Scram (ATWS)
- Interactions between the plant and the grid (measures to protect the plant from transients or functional degradation on the grid)
- Additional safety upgrades that address common cause failure
- Environmental qualification (assurance that the capability of safety-grade equipment and certain other systems and components function as required under accident conditions)
- Performance of a comprehensive set of accident analyses that will support current safety upgrade proposals and identify additional upgrades, if any
- Additional fire protection measures
- Addressing long-term cooling capabilities

The above set is not comprehensive, nor does each upgrade apply to all reactor types Some of these upgrades require engineering studies only, others require engineering studies which may or may not present a rationale for additional construction or equipment installation Some of these studies have been costed in the JPNAS

4 1 2 Confinement/Containment Function Systems

The containment function is not explicitly referred to in the recommendations for the IUG For the purposes of this study, three confinement/containment systems were conceptually designed and costed These were

1) a US style containment system for RBMK-1000 and first generation VVER-440 reactors,

2) a jet condenser pressure suppression system and a metal confinement

structure of Russian design over the operating floor for RBMK-1000,

3) a jet condenser pressure suppression system with some additional confinement elements for the first generation VVER-440 reactors

Note that for the first generation VVER-440 the existing confinement is considered adequate by the Russian experts However, they consider it necessary to improve the pressure withstanding capability of the sealed rooms and implement other measures

Note that risk is not only reduced by design measures, but also by operational improvements Therefore, the Russian safety program includes measures aimed at improving operation and maintenance, quality control, diagnostic methods, administrative controls, personnel qualifications and training, and periodic safety assessments

The construction of a U S style containment at either an RBMK-1000 or a first generation VVER-440 would be technically feasible but very costly because

1) extensive safety-related equipment relocation,
2) a new Seismic Category I structure to house the relocated equipment,
3) demolition of part of the existing rectangular reactor building to make way for a cylindrical containment,
4) incremental tunneling and reinforced concrete and steel liner placement beneath the reactor building to provide a containment mat and a continuous final fission product barrier (liner)

For first generation VVER-440 the jet condenser would be effective for the large LOCA according to the Russian experts Also according to Russian experts, for the RBMK-1000 this same conceptual design should be able to withstand the loss of one pipe manifold The VVER-440/213 reactor design incorporates a bubbler condenser tower, which is one element of the safety systems for accommodating a large break LOCA

4 2 APPROACH TO COST ESTIMATION

4 2 1 Introduction

A US developed Energy Economic Data Base (EEDB[1]) was utilized as a basis and format for developing the cost estimates that were required for this study The EEDB was selected for this

[1] EEDB maintained by Raytheon Engineers and Constructors Inc

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purpose because of its unique capability to achieve consistency and comparability in a variety of cost estimates for dissimilar scenarios

The EEDB cost data models are quantity (materials and related installation hours) driven, reflecting the specific design features of the U S power plants represented by the technical data models The EEDB technical data models are based on historical power plant designs Additionally, the data models have been periodically checked against actual field data to assure compatibility with current U S technical practice and cost experience

The direct costs are estimated in terms of quantities of commodities, equipment and installation labor that reflect the design features of the power plant of interest Costs are developed from the estimated quantities based on actual design features, or adjustments of quantities for representative or similar design features found in the data base

There are two types of estimates in the EEDB Detailed and Summary Detailed cost estimates are based upon a technical data model comprising over 50 major structure/systems and up to 400 subsystems Each detailed technical data model includes system design descriptions, engineering drawings, milestone schedules and a detailed equipment list The equipment list contains up to 1250 mini-specifications and up to 10,000 data lines of plant bulk commodities, equipment and labor hour quantities and costs Summary cost estimates are based on abbreviated technical data models at the 50 major structure/system level of detail

4 2 2 Cost Estimating of JPNAS Options

The cost estimating process began by selecting US based reactors to approximate Russian designs An EEDB costing model of an 1144 MWe, Four-Loop PWR NPP was used as a starting point in estimating the costs of providing safety upgrades RBMK-1000, VVER-440 and VVER-1000 reactors and for completing Kalinin-3

The cost estimate for the evolutionary NP-500 reactor was based on an EEDB model for a 587 MWe Two-Loop Pressurized Water Reactor Nuclear Power Plant

The estimate of direct costs for repowering Rostov-1 is based on actual cost experience of a US contractor for repowering the Zimmer plant in the U S The cost of major equipment items was verified by obtaining price quotations from U S manufacturers Total direct costs were further verified by scaling estimated costs of a fossil plant of similar design in the EEDB The estimates from the EEDB were in agreement with the cost experience for the Zimmer plant Indirect costs were estimated on the basis of experience incorporated in the EEDB Indirect costs were assessed on the basis of US contractor experience incorporated in EEDB

All of these cost estimates were converted from a U S basis to a Russian basis as described in

Section 4 2 5 of this report

4 2 3 Decommissioning Costs

Decommissioning costs have two principle components Direct Impact Costs and Socio-Economic Costs Note that these costs are highly interdependent when a decommissioning strategy includes the goal of maintaining high employment levels at the plant, direct impact costs will be higher and social costs lower Direct impact costs include costs of all on-site and off-site activities directly associated with the decommissioning process Costs not directly associated with decommissioning such as those related to meeting regulatory requirements, operating the spent fuel storage facility and others have been estimated and are reported separately in Appendix C

For RBMK-1000 and first generation VVER-440 NPPs there is a need to install a waste processing/storage facility In addition, RBMK-1000's require a spent fuel storage facility prior to actual decommissioning (VVER-440's do not have the requirement) This is a consequence of the insufficient size of an on-site spent fuel storage facility to accommodate the decommissioning process The costs of those facilities were accounted for in both the Russian and U S approach to decommissioning

Two decommissioning scenarios are considered for each decommissioning approach

Planned	-	reactor is shutdown at the end of service life (EOSL)
Early	-	reactor is shutdown 5 years prior to EOSL

The duration of activities and their manpower resource requirements formed the basis for the present estimate The Russian experts developed the definition of the decommissioning phases, their duration, the outline of activities for each of the phases and the man-power requirements for each activity The period after the final unit is shut down is divided into three sequential phases preparation for decommissioning, preparation for a long-term safestore and the long-term safestore itself (similar to the U S type process with long-term safestore) A detailed description of the phases is provided in Appendix C

The cost estimation for the Russian approach assumed the following breakdown of major activities into phases

<u>Phase 1</u> construction of spent fuel facility (RBMK-1000 only), construction of liquid and solid radwaste processing facilities, processing of accumulated operational radwaste, decontamination of equipment and facilities, site characterization study is performed to address physical inspection and radiological inspection The phase duration is 3 and 5 years for planned and early decommissioning respectively

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Phase 2 Disassembly of equipment and systems (excluding the reactor vessel), localization of reactor in place, processing of liquid and solid radwaste, facility decontamination and preparation for use as temporary storage, storage of spent fuel and radwaste The phase duration is 5 years for both planned and early decommissioning

Phase 3 Custodial activities associated with spent fuel facility operation, radwaste storage, and localized equipment, systems and structures The phase duration is 30 years for both planned and early decommissioning

The U S approach differs from the Russian approach in that it provides for decontamination to be followed immediately by full scale equipment removal without the safe storage phase (Phase 3)

The approach to the assessment of socio-economic costs was the same for both approaches The cost drivers considered in this study for the estimate of socio-economic costs are as follows

- Staffing levels at the units during normal operation
- Staffing levels at the unit during various decommissioning phases
- The duration of the decommissioning broken down into phases
- Town site demographics
- Costs of retraining, relocating, and continued compensation
- Allowance for living accommodations at new location

The extent of the social obligation considered in this study is identical in large measure with those proposed by the Russian Federation Government for social programs for workers in coal and strip mines and mining towns that were stated for shutdown It is also similar to the social guaranties and compensation given to workers laid off from enterprises named in labor legislation and in the Russian Federation law on "Employment of the Populace in the Russian Federation "

For social costs, 50 percent of workers and townspeople that would be displaced by decommissioning were assumed to be transferred to other facilities The transferred people were assumed to be provided with moving expenses only The other 50 percent were assumed to be provided with additional benefits, such as retraining, severance pay and apartment allowances One notable exception pertains to early decommissioning All personnel and prorated town's people displaced at the reactor shutdown time (Phase 1 only) are assumed to receive full benefits

In some cases, substitute heat sources for district heating will be required when NPPs are shutdown for decommissioning These costs have not been estimated in the JPNAS

Not considered in this study is the construction of additional nuclear generating capacity at the site or in the vicinity of a decommissioned reactor unit This scenario would mitigate or completely eliminate the socio-economic cost since the vast majority of personnel employed at the decommissioned NPP would be able to work at the new generating station

4 2 4 Fuel and Non-Fuel Operation and Maintenance (O&M) Costs

Three nuclear fuel costs were estimated on the basis of one set of common assumptions and three sets of specific assumptions The fuel costs are identified as maximum, average and minimum The average cost is used in the reference case of the JEPAS integrating model, while the maximum and minimum costs are used in the sensitivity/change cases The general assumptions and the specific underlying assumptions of each cost are provided in Annex 2

Non-fuel O&M costs were derived on the basis of applying the U S Department of Energy (DOE) methodology using input staffing tables provided by the Russian experts for each reactor type

4 2 5 Conversion of U S Based Cost Estimates to a Russian Basis

The EEDB methodology reflects U S construction practices, wages, equipment costs and commodity prices Thus, it is necessary to establish adjustment factors for converting the economic conditions reflected in the EEDB to Russian economic conditions and construction practices

Two systems of converting the assessed U S costs into the Russian conditions were developed in the study As the methodology of JPNAS proceeded from the assumption of the necessity of the conversion procedure, JPNAS has put an effort to develop such a procedure from the very beginning of the study The results of similar developments by the Russian Energy Research Institute (ERI) for the JEPAS became available in August 1994 The major difference in the development of the conversion factors is that the JPNAS developed average factors for the whole period under consideration while the JEPAS factors change explicitly with time It was decided to apply the factors developed by ERI for the JEPAS as the reference case and the factors developed by the JPNAS as a case for sensitivity analysis

The recommendations reached in the analysis of the JPNAS are based mostly on intuitive judgment and the following assumptions

1 The cost of engineering services reflects an average U S rate of $35/hr (January 1994) excluding overheads and profit

2 Russian Engineering costs are based on the Ernst & Young Moscow Salary Survey of January 1994

3 Social Costs normally provided for in Russia, such as housing, medical care, schooling, etc are not reflected in any comparisons of cost

4 The factors for equipment and materials (other than concrete and structural steel) assume that the Russian economy will continue to change in the direction of market based pricing and will eventually be as competitive as the world market

5 Concrete and structural steel are assumed to be higher in cost due to demand of infrastructure and housing construction

6 It is assumed that the Kalinin 3 Station construction data reflects typical construction manpower staffing levels and that no major "off-site" construction is included, i e logistic infrastructure, gravel pits, processing facilities etc Direct and indirect labor productivities are based on a direct comparison of actual total project man-hours for the construction of Kalinin units 1 and 2 and the EEDB estimate for a similar project

7 Construction labor cost comparison assumes that the relationship between average labor cost and cost of construction labor will remain the same as in the past (construction 30% higher)

8 For professional services is was assumed that this sector of the labor market would most readily adapt to a more independent employment approach and be less dependent on government support

9 The factor for construction labor salaries is based on a highly speculative value for average labor costs in Russia of 256 000 Rb/Month (January 1, 1994)

The JPNAS factors are provided in Table 4-1 The factors obtained by ERI for the JEPAS for 1994 are presented in Table 4-2 Note that the cost of labor in Table 4-2 includes not only salary but all required labor expenditures These factors represent the ratios of the stated parameters (prices and labor productivity) for Russia to the United States

4 2 6 Cost Contingency

The amounts in the row marked "contingency" in the tables of Annex 3 are added to the base construction cost (BCC) estimate to ensure a pre-selected confidence level of "no-cost-overrun", i e , that the BCC plus the contingency will not be exceeded It reflects the uncertainty of the estimator of the BCC In this respect it is only partially analogous to contingencies which are included in a bid for, say, a construction contract where the contingency reflects an element of uncertainty but is strongly constrained by anticipated competition from other bidders[2]

Note that in the tables, contingencies range from a high of about 30 percent to a low of 10 percent

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[2] Contingencies are based on the EPRI Technical Assistance Guide

While contingencies remain largely subjective, the EEDB provides guidelines and procedures for arriving at contingency values

Table 4-1 JPNAS Factors for Converting a U S Conditions Cost Estimate to a Russian Conditions Cost Estimate

Conversion Item	Factor
Equipment	0 70
Concrete	1 00
Structural Steel	0 55
Other Commodities	0 70
Direct and Indirect Labor Productivity	2 50
Professional Services	0 15
Construction Labor	0 10

Table 4-2 ERI Factors for Converting a U S Conditions Cost Estimate to a Russian Conditions Cost Estimate for 1994

Conversion Item	Factor
Equipment	0 50
Construction Materials	0 70
Metals	0 75
Labor	0 10

5 0 COST EVALUATION RESULTS AND OBSERVATIONS

5 1 INTRODUCTION

One of the major objectives of the JPNAS was to develop cost estimates for Russian nuclear power plant (NPP) options discussed in Section 3

These estimates have been prepared to provide data essential to the operation of an integrating model, i e , an integrated resources plan and the relevant investment requirements They do not cover all of the cost elements required as input data for an integrating model Consequently, these estimates in and of themselves are not useful for determining optimum choices from the group of considered alternatives

A total of 69 overnight base construction cost (BCC) estimates were prepared to support the JPNAS Final Report They are given in Annex 3 (in brief) and Appendices B and I (in detail)

An "overnight" cost estimate is one which assumes that the plant construction or decommissioning activities occur at once, thereby accruing no interest The advantage of this approach is that the estimates are not encumbered with arbitrary or controversial time-related factors The disadvantage is that estimates having varying time-lines may be inadvertently compared on an equal basis without the time relationship to costs being taken into consideration

In addition to providing BCC estimates, operating and maintenance (O&M) costs of the existing and new nuclear power units were estimated

5 2 COST ESTIMATE TABLES

The BCC and O&M costs were estimated as constant January 1, 1994 U S dollars They are summarized in the tables in Annex 3 Separate estimates based on conditions that prevail in the U S and on Russian conditions are provided

For convenience, the tables presenting BCC estimates in Annex 3 are separated into three separate parts as follows

Part A BCC in thousands of constant 01/01/94 U S dollars, including direct, indirect, owner's and contingency costs, in an Energy Economic Data Base (EEDB) major system/structure code of accounts

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Part B The same costs as in Part A expressed as a percentage of the total BCC

Part C The same costs as in Part A expressed as dollars per gross kilowatts, electric ($/kWe)

While the summary overnight BCC may be found in Part A, cost drivers may be identified in Part B and the costs normalized to capacity and activity duration may be reviewed in Part C Additionally, the last line of the A and C tables show the Present Worth of the BCC with Contingency, also in gross $/kWe In addition, two cost estimates for the Russian conditions are given based on the JPNAS and the JEPAS factors

The costs in the tables are presented as maximum and minimum estimates The maximum assessment for each option is the maximum cost of upgrade implementation among all the units considered A similar definition is used for the minimum estimates

The O&M costs are presented in terms of Fixed and Variable costs Fixed costs are those which are independent of the units output, such as staff salaries, and are given in dollars per kilowatt-year ($/kW-yr) Variable costs are those which vary with the unit's output, such as expendable supplies, and are given in mills/kilowatt-hour (mills/kWh)

5 3 COST ESTIMATE BASES

5 3 1 Base Construction Costs

The costs were first developed by US experts from EEDB detailed data models (U S basis), then modified by detailed technical data provided by Russian experts to reflect actual Russian NPPs, and finally converted to Russian conditions, based on the conversion factors found in Tables 4-1 and 4-2 in Section 4

In the summary tables, the BCC are the sum of the Direct Costs and the Indirect Costs The Direct Costs are summarized in the tables in Annex 3 as total Equipment Cost, Labor Hours, Labor Cost and Material Cost

For each system or facility the following procedure for direct cost estimation was implemented

1 U S experts selected the design prototype for the system/facility from the EEDB

2 the prototype parameters such as mass, size, capacity etc were refined and

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corrected on the basis of detailed technical information provided by the Russian experts

3 the cost estimation of the system/facility was computed on the basis of the corrected parameters

For each unit the Indirect Costs, Owner's Costs, Contingencies and "Totals" were calculated for the Direct Cost in accordance with EEDB procedures and methodology Indirect Costs were calculated by taking into account magnitude and type of construction, craft labor requiring supervision, engineering costs and construction duration The Owner's Cost and contingency for each unit are calculated as a percentage of the BCC, The percentages were taken from the EPRI 1993 Technical Assessment Guide

The estimates were based on actual and planned nuclear power units located at seven current sites and two future sites in Russia The specific data for the individual units were provided by the Russian experts The economies associated with multiple units on a single plant site were considered and are reflected in the cost estimates

5 3 2 O&M Costs

The Non-Fuel O&M costs were developed on a Russian basis from EEDB procedures and data These costs were based on detailed unit staffing levels provided by the Russian experts and an estimated relative allowance for expendable materials The non-fuel O&M costs were developed in terms of both Fixed and Variable costs It was agreed among the JPNAS (Russian and American) experts that the large staffs at Russian units could absorb the additional O&M work resulting from exercise of the various operational options, without a staff increase As a result, no change occurred in the non-fuel O&M costs after application of a JPNAS operational option to an existing unit

The Fuel costs were developed by the Russian experts The costs and methodology used in deriving them are found in Annex 2

5 4 CONSTRUCTION SCHEDULES

This section discusses the bases on which construction schedules were developed to support the cost estimation efforts and the establishment of cash flow information

5 4 1 Schedules for the Operational Options

Construction schedules for all options were developed from the American and Russian experts' experience and EEDB data and approach These schedules, based on a continuous construction

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duration, formed one of the essential bases for the calculation of each option's indirect cost and were used in the integrating model

The actual approach to the implementation of safety upgrades for Russian NPP's are discussed in more detail in Section 2 3

The construction durations, including the unit shutdown and construction times, for all options are provided at the bottom of the cost estimate tables in Annex 3

5 4 2 Schedules for the Decommissioning Option

Durations for planned and early decommissioning were developed by the JPNAS experts based on Russian data Planned decommissioning was assumed to start at the unit's end-of-service-life Units which needed to be shut-down to implement upgrades had their end-of-service-life date extended by the duration of the upgrade shut-down period There are many possible scenarios for early decommissioning As a result of the scope of this study, only one early decommissioning scenario was assessed In this scenario, early decommissioning was arbitrarily assumed to start five years prior to the end-of-service-life The differences between the estimates, i e , the incremental costs of decommissioning, are relatively modest The resulting decommissioning initiation dates and estimated durations are summarized in the tables in Annex 3

5 5 COST ESTIMATE OBSERVATIONS

Based on the technical and cost evaluations performed in the JPNAS, the following observations need to be noted

5 5 1 General Considerations

District Heating RBMK-1000 and VVER-440 NPP units supply heat for district heating When they are decommissioned or shut-down for upgrading (e g , to install the containment function), depending on the existence of other heat sources at the site, an alternative district heating source may be required No cost allowances for such alternative sources have been included in any of the JPNAS cost estimates

Site Conditions No allowance was made in any of the BCC for extreme meteorological or geological conditions existing at a unit site (e g , the Kola site, which is North of the Arctic Circle) It was assumed that any atypical costs that might result because of such conditions would be sufficiently moderate that they would be covered by the unit contingency allowance

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<u>Higher BCC of a First-Unit-on-Site</u> Users of the BCC data should be aware that the JPNAS cost estimating ground rules may cause the first unit on a site to have a higher cost than other units on the same site This situation may occur for two reasons 1) costs of common site facilities (e g , addition of a site radiation monitoring system) were charged to the first unit (Unit 1), and 2) multi-unit cost savings were applied to Units 2, 3 and 4 as appropriate Therefore, users of this data cannot reject the Unit 1-2 costs in favor of the Unit 3-4 costs on a four-unit site, in order to make use of the lower costs associated with the Unit 3-4 pair Multi-unit cost savings were applied where modifications or construction were identical for two or more units

5 5 2 Safety Upgrades for Units with the RBMK-1000 and First Generation VVER-440 Reactors

This option includes the structural costs for a confinement plus jet-condenser or alternatively a U S style containment addition In both cases, the cost for the full containment alternative is approximately two to three times higher than the cost for the confinement/jet-condenser approach

The higher cost for adding a U S style containment to an existing NPP reflects the need for expenditures beyond those for the containment itself These expenditures include costs for

1) extensive safety-related equipment relocation,

2) a new Seismic Category I structure to house the relocated equipment,

3) demolition of part of the existing rectangular reactor building to make way for a cylindrical containment, and

4) incremental tunneling and reinforced concrete and steel liner placement beneath the reactor building to provide a containment mat and a continuous final fission product barrier (liner)

Although American demolition and tunneling experts believe that the approach is conceptually feasible, they also believe that caution should be exercised in committing to such a venture Consequently, the cost estimate is based on the assumption that no substantial implementation barriers arise once the effort is undertaken

As noted in Section 2 3, some recommended upgrades are already implemented and, therefore, are not costed In other cases, recommended upgrades are partially completed or are under way and, consequently, are either not costed (if the upgrade was expected to be completed soon) or are proportionally costed based upon the percent complete The status of the safety upgrades was determined during a series of meetings between JPNAS experts and the staff of Rosenergoatom

5 5 3 Decommissioning of RBMK-1000 and First Generation VVER-440/230 Reactors

Decommissioning costs include only person-hours that were attributable to decommissioning plus all of the social costs related thereto, per Russian law Based on decisions made by Russian regulatory bodies, it is assumed that a substantial complement of personnel will be retained at each NPP after shutdown It was expected that these personnel would remain as long as nuclear fuel remains at the unit, a period estimated at three years To the extent that they were not required to support decommissioning, retained personnel were not charged to decommissioning The question of appropriate allocation of these costs remains open Nevertheless, these personnel were included in the social cost calculations, because their displacement is eventually required

Generally, the decommissioning cost estimates would include no direct construction costs In the case of the RBMK-1000 and first generation VVER-440, however, it was necessary to make an exception These NPPs store their radwaste on-site over the life of the plant Consequently, costs for the construction of a radwaste facility, to process the accumulated radioactive liquid and solid waste, needed to be included in the decommissioning costs for these units In addition, the RBMK-1000 required construction of an additional on-site fuel storage facility to aid in the defueling of the reactor These costs were added to the Russian and U S Approach decommissioning costs as direct and indirect costs

Since the U S Approach included these BCC, as well as the Russian social costs, the U S Approach bottom-line is considerably larger than what is expected for decommissioning costs in the U S The U S Approach without the BCC, social costs and contingency added for this study was estimated as about $200x10^6$ 01/01/94 U S dollars for the 1000 MWe RBMK and about 172x10 01/01/94 U S dollars for the 440 MWe VVER

As in the first Option above, the JPNAS cost estimating ground rules may cause the first decommissioned unit on a site to have a higher cost than other units on the same site The reason for this situation is different The BCC for common site facilities (radwaste processing facilities and additional fuel repositories) were charged to Unit 1 Therefore, users of these data cannot reject the costs of Unit 1 in favor of the costs of other units on a multi-unit site, in order to make use of their lower costs

In the Russian Approach, decommissioning costs for the RBMK-1000 were considerably higher than for the first generation VVER-440 This is a consequence of the substantially higher RBMK-1000 plant staffing level

It is necessary to note that decommissioning costs can be different for different units In this study, the cost for the Kursk-1 RBMK-1000 and the Novovoronezh VVER-440 were investigated in detail, and these results were extrapolated for all the other units

5 5 4 Repowering Rostov-1 as a Coal-Fired Plant

Since this option was considered to be a "What-If" case, no consideration was given to replacing the initial planned total plant capacity with an equal conversion capacity, and existing facilities were assumed to be available at no cost

No allowance was made in this Option BCC to account for "tie-in" to the Russian grid or for any transmission improvements that may be required to support the capacity added

5 5 5 Completion of the Kalinin-3 VVER-1000

This option combines the simultaneous completion and upgrade of an uncompleted unit It was assumed that the uncompleted unit was 75 percent complete Consequently, many of the upgrade tasks may be done as new construction and all of the upgrades will be done in non-hazardous areas, since the unit has not yet operated The completion part of the estimate is the major contributor to cost, or about 66 percent of the overnight BCC The remaining 34 percent represents the cost of the upgrades, and in some cases new construction In addition, costs for this option were extrapolated to provide assessments for the completion costs of Balakovo units 5 and 6, Kursk unit 5, and Rostov unit 1 These units are 30, 15,75, and 90 percent complete respectively

5 5 6 Safety Upgrades to Operating Plants with VVER-1000 AND VVER-440/213 Reactors

As in the first option, some of the recommended upgrades are already completed, while others are partly completed None of the completed upgrades are costed The partly completed upgrades were also not costed because they were expected to be completed soon The cost of the upgrades in this option are higher than the costs of upgrades in the previous option because all of the upgrades need to be done on a re-construction basis and allowance must be made for re-construction in a hazardous area

5 5 7 New Evolutionary Nuclear Power Plant NP-500

To perform the cost estimate for the new generation reactor, the NP-500 and U S conditions were selected as a basis Direct cost estimates were done for construction of first-of-two and second-of-two NP-500 units on a site The NP-500 has an estimated cost that is close to current published estimates for the Pressurized Water Reactor version of the Passive Advanced Light Water Reactor currently being developed in the U S (AP-600)

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No allowance was included in the New Generation Option BCC to account for "tie-in" to the Russian grid or for any transmission improvements that may be required to support the capacity added at the New Generation site

5 6 Present Worth Normalization

The present worth normalization was included because the cost estimates were done on an "overnight" cost basis, while the actual construction or decommissioning activities cannot be done overnight To calculate the present worth, annual cash flow patterns assessed by JPNAS experts were used, see Appendix I A discount rate of 12% was used

6 0 GENERAL CONCLUSIONS AND RECOMMENDATIONS

6 1 COST ESTIMATION RESULTS

The JPNAS assessed costs and activity durations for six options for the Russian nuclear power sector 1) safety upgrades of NPPs with RBMK-1000 and first generation VVER-440 reactors, 2) decommissioning of NPPs with RBMK-1000 and first generation VVER-440 reactors, 3) completion of an NPP with the VVER-1000 reactor, 4) repowering of an incomplete NPP into a fossil fuel plant, 5) safety upgrades of NPPs with VVER-1000 and second generation VVER-440 reactors, 6) construction of new generation NPPs The resulting cost estimates are summarized in Tables 6-1,6-2 and 6-3 and in Annex 3

These assessments allow for the determination of the viability of the considered options with regard to the investment amounts and implied activity durations This data, coupled with similar data for the other electric power sector alternatives can be used to provide recommendations for the optimal development of the Russian power sector in the framework of an integrating economic model

All JPNAS cost assessments have been developed on the basis of detailed technical data provided by Russian experts The costs assessments have been prepared by U S experts in accordance with the procedures and methodology of the EEDB The implementation schedules for all options have been prepared on the basis of U S experience and then corrected on the basis of Russian experience Starting dates for the upgrades and implementation schedules were suggested by Russian experts

The salient conclusions drawn from the estimates and the study are the following[1]

<u>Safety Upgrades for Units with the RBMK-1000 and First Generation VVER-440 Reactors</u>

The concern of the world community about the safety of further operation of Russian NPPs (mainly NPPs with the RBMK-1000 and first generation VVER-440 reactors) was one of the premises of the JEPAS and, correspondingly, of the JPNAS Thus, the cost assessment of safety upgrades of these reactors was a key issue of the JPNAS

Safety upgrades to Russian reactors required so that they may operate until the end of service life at an increased level of safety have been identified by Russian and American engineers Many of them have been completed while others are currently in the process of implementation, financing being provided by Russia, these completed and almost completed upgrades have been excluded from consideration in JPNAS This has resulted in a decrease in the upgrade costs compared with the costs provided in the JPNAS Interim Report

[1] All numerical results in this Section are overnight costs and pertain to Russian conditions using conversion factors supplied by ERI for use by the JEPAS

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Full containment systems for RBMK-1000 and first generation VVER-440 units have been costed at the request of US experts The U S style containment system for these reactors is technically feasible but very costly

The evaluated costs of safety upgrades to the RBMK-1000 units ranged from 35 to 90 million USD for the confinement and jet condenser designs, and from 136 to 228 million USD for the full containment designs

The evaluated costs of safety upgrades to the first generation VVER-440 units ranged from 29 to 39 million USD for the confinement and jet condenser designs, and from 87 to 111 million USD for the full containment

Decommissioning of RBMK-1000 and First Generation VVER-440/230 Reactors

The JPNAS assessed the cost of decommissioning units with RBMK-1000 and first generation VVER-440 reactors The cost assessments for decommissioning included direct costs and social costs calculated in accordance with the Russian law Two approaches were considered a Russian approach and a U S approach

The Russian approach to decommissioning was based on data provided by the Russian experts and was used as the reference case in the JEPAS This approach assumes a long-term safe storage of the plant until the time of final dismantling The Russian Approach is based on Russian Federation studies tempered by maintenance, repair and replacement experience As such, it reflects decommissioning procedures that regulatory and utility organizations find acceptable in the Russian Federation today

The U S approach is based on the same Russian data and the results of U S studies tempered by the evolutionary effects of actual experience It is based on a process with immediate full plant dismantling

The U S approach to decommissioning Russian nuclear power plants was developed as a hypothetical case, on the basis of nuclear regulation, financial conditions and the technology base existing in the U S This resulted in differences between the costs of Russian and U S approaches to decommissioning However, there are large technical uncertainties for both approaches, for example, the handling of the irradiated graphite from RBMK's The impact of such uncertainties, in terms of cost and durations, is different for the US and Russian approaches Therefore, direct quantitative comparison of the respective overall cost estimates is not justified and neither approach can clam to be optimal However, the US approach was used as a change case in the system analysis to test for the sensitivity to decommissioning costs

An effort to find an optimal approach in either country might prove to be highly cost effective

Providing assistance in achieving this goal is addressed in Section 6 2

The assessment of decommissioning costs has been prepared for two scenarios planned and early decommissioning The difference in cost between the two, i e , the incremental cost of decommissioning, turned out to be rather moderate However, this comparison is based on overnight construction costs and does not include the cost of compensating generation capacities

The construction of additional nuclear generating capacity at the site or in the vicinity of a decommissioned reactor unit will mitigate or completely eliminate the socio-economic cost

The evaluated costs of the planned decommissioning of RBMK-1000 units ranged from 169 to 198 million USD for the Russian approach, and from 49 to 78 million USD for the US approach The evaluated costs of the planned decommissioning of VVER-440 units ranged from 108 to 124 million USD for the Russian approach, and from 48 to 64 million USD for the US approach

The evaluated costs of the early decommissioning of RBMK-1000 units ranged from 172 to 200 million USD for the Russian approach, and from 52 to 81 million USD for the US approach The evaluated costs of the early decommissioning of VVER-440 units ranged from 109 to 125 million USD for the Russian approach, and from 49 to 65 million USD for the US approach

Repowering Rostov-1 as a Coal-Fired Plant

The cost of repowering Rostov-1 as a fossil fuel plant was estimated at $557 million USD According to the concept of repowering, which formed the basis with this estimate, certain items of the partially completed nuclear power plant could be utilized While the repowered plant would have a capacity of 1500 MW as compared to 1000 MWe capacity of the nuclear plant, the cost on a kilowatt basis of the fossil plant would be substantially greater than the cost of completing the 95 percent complete nuclear plant

This option had the highest capital and O&M costs of the six options evaluated by the JPNAS In addition, to implement the repowering, substantial fossil fuel resource development and railroad capacity would be required Site development for coal storage and ash disposal would also be needed JPNAS has not estimated these costs

Completion of the Kalinin-3 VVER-1000

The cost of completing this reactor (75 percent complete) with safety upgrades was estimated at 146 million USD The plant can be completed at a modest cost

Safety Upgrades to Operating Plants with VVER-1000 AND VVER-440/213 Reactors

The cost of providing these upgrades was estimated in the JPNAS The approach to the prioritization of upgrades for these reactors is the subject of a task for further effort and is discussed in Section 6 2

The evaluated costs of safety upgrades to operating VVER-1000 units ranged from 16 to 29 million USD

The evaluated costs of safety upgrades to operating VVER-440/213 units ranged from 11 to 14 million USD for designs using the confinement and jet condensor approach, and 69 to 86 million USD for designs using the full containment approach

New Evolutionary Nuclear Power Plant NP-500

This evolutionary power plant of innovative design is now approaching realization This plant gives the promise of providing substantially higher levels of safety and reliability than those in operation today This is achieved by applying passive safety systems and providing a double protective containment shell This project is characterized by a compact design leading to reduced material quantities and more effective space utilization Projected man-power requirements are substantially less than for the operating reactors This innovative concept provides a technological basis for expansion of nuclear power generation in Russia and for the penetration of foreign markets by Russian technology Russia is planning to build NPPs of this type as replacement capacities and at several new sites In order to be licensed in a manner consistent with international practice there is a need for verification and substantiation of these new innovative safety features This is addressed in Section 6 2

The evaluated costs of construction of an NP-500 are 529 million USD for the first unit and 440 million USD for the second unit (assuming a two unit plant)

Other Results and Observations

The assessments made in the context of JPNAS show that fuel resources and the required infra-structure exist in Russia for supplying fuel to all existing nuclear power plants at current levels of production now and for the foreseeable future Resources and infra-structure exist in Russia to support the production of most nuclear power plant components required for power plant completion, safety related upgrades and new power plant construction

6 2 RECOMMENDED PROJECTS FOR IMPLEMENTATION

The paragraphs which follow identify projects for early financing and implementation which would facilitate achieving the nuclear objectives delineated in the TOR Implementation of these projects is advantageous for various reasons regardless of selection by the integrating model as part of a least cost strategy They are

1) Development of the optimal implementation strategy for safety upgrades of operating NPPs

2) The development of a decommissioning program for a specific RBMK-1000 reactor

3) Completion of the design of the NP-500 and NP-1000 (new generation evolutionary reactors) to a sufficient level of detail so as to allow a full-scale licensing process

6 2 1 Development of an Optimal Implementation Strategy for Safety Upgrades of Operating NPPs

In the JPNAS, the costs of the implementation of various safety upgrades have been developed The Russian and international expert groups have conducted many studies of the safety of Soviet-designed NPPs

This project would develop and implement a methodology allowing the ranking of the suggested safety upgrades in accordance with their efficiency so that the maximum economic benefit of the investments in safety upgrades could be ensured, taking into account the financial constraints This could be done based on the following

1) the studies already performed,

2) the available experience and knowledge on the specific safety systems and the facility as a whole, and

3) some additional studies involving Probabilistic Safety Assessments (PSA),

As a continuation of this activity and as the recommendations for IUG include PSAs for each operating VVER, it is proposed that a level 1 and 2 PSA be performed for an operating unit, e g Balakovo-1 A generic PSA for the VVER-1000 is currently in process as a joint US/Russian project Application of the generic PSA methodology to a specific Russian power plant performed by Russian engineers would complete the technology transfer inherent in the PSA project Many problems in the PSA process have been identified and solved by US engineers This knowledge would be used to assist Russian engineers to improve their PSA methodology

6 2 2 Development of a Decommissioning Program for a Specific RBMK-1000 Reactor

A JPNAS conclusion is that Russian planning for decommissioning is not at the stage where the decommissioning of a specific plant can be accomplished At present, the level of maturity of the

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Russian approach to decommissioning is characterized by incompleteness of comprehensive regulatory guidance and the absence of options for the disposition of spent fuel and radwaste Thus, it is difficult to optimize technological and cost parameters

The project would include the identification of an RBMK reactor which is likely to be decommissioned in the near term In this context, the following objectives would be addressed

- Recommend appropriate regulatory development
- Specify details and progression of decommissioning activities
- Develop detailed cost and schedules
- Identify US technology that would support and facilitate NPP decommissioning in Russia

The results of this project would be applicable to the decommissioning of other units with RBMK reactors

6 2 3 Completion of the Design of the NP-500 and NP-1000 (New Generation Evolutionary Reactors) to a Sufficient Level of Detail So as to Allow a Full-Scale Licensing Process

The NP-500 and NP-1000 are approaching design completion These designs include passive and active systems Many of them are innovative and require verification of design and operational reliability including environmental qualification The proposal is that Russian engineers undertake this verification and optimization of design features with the support of US experts, facilitating the licensing of the NP-500 and NP-1000 consistent with international practice

Additionally, to assist in the design and construction process this project would provide Russian engineers with cost estimating and project management tools Such tools will be useful across the entire spectrum of electric sector projects

Table 6-1
"OVERNIGHT" BASE CONSTRUCTION COST ESTIMATE SUMMARY
U S CONDITIONS
(IN CONSTANT JANUARY 1 1994 DOLLARS)

Option Description			Project[1] Duration (Months)	Total Cost[2]	
				High/Low (10^6 $)	High/Low ($/kWe)[3]
Option 1 Continuation	With Confinement and Jet Condenser	RBMK-1000 (1000 MWe)	24	224/87	224/87
		VVER-440/230 (440 MWe)	21	115/89	262/202
	With Full Containment	RBMK-1000 (1000 MWe)	36	649/429	402/87
		VVER-440/230 (440 MWe)	36	365/286	829/650
Option 2 Planned Decommissioning	Russian Approach	RBMK-1000 (1000 MWe)	516	1253/1185	1253/1185
		VVER-440/230 (440 MWe)	516	640/600	1455/1364
	U S Approach	RBMK-1000 (1000 MWe)	144	427/360	427/360
		VVER-440/230 (440 MWe)	120	332/292	755/664
Option 2 Early Decommissioning	Russian Approach	RBMK-1000 (1000 MWe)	480	1279/1212	1279/1212
		VVER-440/230 (440 MWe)	480	648/608	1473/1382
	U S Approach	RBMK-1000 (1000 MWe)	144	457/391	457/391
		VVER-440/230 (440 MWe)	120	776/685	136/22
Option 3 Conversion of a VVER-1000 to Organic Fuel(1500 MWe)[4]			24	1457	1457
Option 4 Completion/Upgrade of a VVER-1000 (1000 MWe)[4]			26	561	561
Option 5 Upgrade of a VVER-440 /213 (440 MWe)			21	50/40	114/91
Option 5 Upgrade of an Operating VVER-1000 (1000 MWe)			18	97/58	97/58
Option 6 New Generation NP-500 (635 MWe)			48	1455/1164	2291/1833

1 RBMK Project Duration 1 year shutdown for jet condenser/confinement 3 year shutdown for full containment Both include fuel channel replacement
VVER Project Duration 6 month shutdown for jet condenser/confinement 3 years for full containment
2 Base construction cost with owner s cost and contingency
3 Based on Gross Electric Capacity
4 Only one unit evaluated

Table 6-2
"OVERNIGHT" BASE CONSTRUCTION COST ESTIMATE SUMMARY RUSSIAN CONDITIONS USING JPNAS CONVERSION FACTORS
(IN CONSTANT JANUARY 1 1994 DOLLARS)

Option Description			Project[1] Duration (Months)	Total Cost[2] High/Low (10^6 $)	Total Cost[2] High/Low ($/kWe)[3]
Option 1 Continuation	With Confinement and Jet Condenser	RBMK-1000 (1000 MWe)	24	126/49	126/49
		VVER-440/230 (440 MWe)	21	61/50	138/116
	With Full Containment	RBMK-1000 (1000 MWe)	36	334/214	334/214
		VVER-440/230 (440 MWe)	36	174/140	395/319
Option 2 Planned Decommissioning	Russian Approach	RBMK-1000 (1000 MWe)	516	209/169	209/169
		VVER-440/230 (440 MWe)	516	131/108	297/245
	U S Approach	RBMK-1000 (1000 MWe)	144	131/92	131/92
		VVER-440/230 (440 MWe)	120	104/81	236/184
Option 2 Early Decommissioning	Russian Approach	RBMK-1000 (1000 MWe)	480	212/172	212/172
		VVER-440/230 (440 MWe)	480	132/109	299/247
	U S Approach	RBMK-1000 (1000 MWe)	144	134/95	134/95
		VVER-440/230 (440 MWe)	120	105/82	238/186
Option 3 Conversion of a VVER-1000 to Organic Fuel(1500 MWe)[4]			24	792	528
Option 4 Completion/Upgrade of a VVER-1000 (1000 MWe)[4]			26	243	243
Option 5 Upgrade of a VVER-440 /213 (440 MWe)			21	23/19	53/44
Option 5 Upgrade of an Operating VVER-1000 (1000 MWe)			18	48/28	48/28
Option 6 New Generation NP-500 (635 MWe)			48	792/634	1247/998

1 RBMK Project Duration 1 year shutdown for jet condenser/confinement 3 year shutdown for full containment Both include fuel channel replacement
VVER Project Duration 6 month shutdown for jet condenser/confinement 3 years for full containment
2 Base construction cost with owner s cost and contingency
3 Based on Gross Electric Capacity
4 Only one unit evaluated

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Table 6-3
"OVERNIGHT" BASE CONSTRUCTION COST ESTIMATE SUMMARY
RUSSIAN CONDITIONS USING ERI CONVERSION FACTORS
(IN CONSTANT JANUARY 1 1994 DOLLARS)

Option Description			Project[1] Duration (Months)	Total Cost[2] High/Low (10^6 $)	Total Cost[2] High/Low ($/kWe)[3]
Option 1 Continuation	With Confinement and Jet Condenser	RBMK-1000 (1000 MWe)	24	90/35	90/35
		VVER-440/230 (440 MWe)	21	39/29	90/66
	With Full Containment	RBMK-1000 (1000 MWe)	36	228/136	228/136
		VVER-440/230 (440 MWe)	36	111/87	252/198
Option 2 Planned Decommissioning	Russian Approach	RBMK-1000 (1000 MWe)	516	198/169	198/169
		VVER-440/230 (440 MWe)	516	124/108	282/245
	U S Approach	RBMK-1000 (1000 MWe)	144	78/49	78/49
		VVER-440/230 (440 MWe)	120	64/48	145/108
Option 2 Early Decommissioning	Russian Approach	RBMK-1000 (1000 MWe)	480	200/172	200/172
		VVER-440/230 (440 MWe)	480	125/109	284/247
	U S Approach	RBMK-1000 (1000 MWe)	144	81/52	81/52
		VVER-440/230 (440 MWe)	120	65/49	147/110
Option 3 Conversion of a VVER-1000 to Organic Fuel(1500 MWe)[4]			24	557	371
Option 4 Completion/Upgrade of a VVER-1000 (1000 MWe)[4]			26	146	146
Option 5 Upgrade of a VVER-440 /213 (440 MWe)			21	14/11	32/25
Option 5 Upgrade of an Operating VVER-1000 (1000 MWe)			18	29/16	29/16
Option 6 New Generation NP-500 (635 MWe)			48	529/440	833/693

1 RBMK Project Duration 1 year shutdown for jet condenser/confinement 3 year shutdown for full containment Both include fuel channel replacement
VVER Project Duration 6 month shutdown for jet condenser/confinement 3 years for full containment
2 Base construction cost with owner s cost and contingency
3 Based on Gross Electric Capacity
4 Only one unit evaluated

Terms of Reference for a Joint Russian-American Energy Alternatives Study April 18, 1994

To develop a long-term, comprehensive investment program for the Russian power sector in response to the request of Prime Minister Chernomyrdin and Vice President Gore

Background

At the July, 1992, Munich Summit, the G-7 countries expressed their concern about the safety of certain Soviet-designed nuclear power plants and commissioned the World Bank and the International Energy Agency (IEA) to investigate replacement sources of energy and their cost implications The result, a report entitled "Russia Electricity Options," jointly drafted by the government of Russia, the World Bank, and the IEA, was submitted to the G-7 in June 1993

At the G-7 Tokyo Summit (July 1993), the participants urged development of a framework for coordinated action among donor countries and multilateral financial institutions to assist Russia and other relevant countries with long-term energy planning to enable earliest possible closure of their riskiest nuclear reactors This framework is to be considered at the July 1994 G-7 Summit

On September 1 and 3, 1993, Prime Minister Chernomyrdin and Vice President Gore, meeting in the context of the U S - Russia Joint Commission on Economical and Technological Cooperation (JCTC), in keeping with the G-7 framework development effort, agreed on a joint effort to examine options for Russia's energy future Work was to be completed expeditiously, in time for use in preparing for the 1994 G-7 Summit, in time to provide input for upcoming Russian budget and investment planning, and in time to allow for proper integration in international financial institutions' fiscal 1996 lending programs

At the time of the second session of the JCTC on 16 December 1993, Prime Minister Chernomyrdin and Vice President Gore made a joint statement reaffirming the agreement of the two sides to carry out the above-mentioned study

Objectives

The Russian electric power sector will require major investments over the coming decades The sector's main problems include the high proportion of thermal generating plants which are currently beyond-their planned operational lifespans, doubts about the safety of older nuclear plants, and highly inefficient patterns of electricity use In the present state of the Russian economy, federal

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budget financing of power sector development has all but ended while new financing mechanisms appropriate to a market economy have not yet developed

The international community, including the leaders of the G-7 group, attach great importance to joint efforts in helping to solve these problems Fundamental conditions of investment in this most important sector of the Russian economy should be identified on a priority basis

Russian and U S policy makers share a number of objectives in regard to the Russian power sector

- Achieving a major reduction in the risk of nuclear accidents,
- Improving the environmental and safety impacts of the power sector, including the reduction of greenhouse gases,
- Increasing the efficiency of energy use, thereby contributing to Russian industrial competitiveness and growth, helping to balance the Russian budget through an increased exportable energy surplus and helping to reduce environmental impacts,
- Assisting in the transition of this vital sector to market relationships So doing will open the way for new financing mechanisms and will help to contribute to economic health and political stability
- Formulate basic principles and long-term priorities for cooperation based on a balancing of Russian and other countries' interests Identify guiding rules and legislation for long-term cooperation in the power sector on the basis of international law, including the basis for utilization of each country's intellectual property, know-how, and technology,
- Identify the financial models most acceptable to Russia for attracting foreign capital (ownership and stock issues, loan conditions, etc),
- Work out a long-term, mutually-beneficial, comprehensive program of foreign investment in the Russian power sector, identifying priority directions and concrete projects

<u>Study Scope, Goals and Deliverables</u>

The goal of the study is to provide, on the basis of an objective assessment of Russia's energy alternatives in keeping with the objective above, a time-phased investment program for the period 1995-2000 This investment program will include preliminary engineering, feasibility analyses, cost estimates, investment requirements, and financing plans It will consider the Russian energy strategy for bringing future electric supply and demand into balance, including both conventional and nuclear power options in addition to demand-side efficiency measures, allowing for other scenarios as appropriate The analysis also will consider the economic, financial, social, political, environmental, and trade impacts of each alternative strategy This will require expanding significant portions of the study towards the year 2010 A tight regional focus will also be required to meet project completion deadlines and to ensure that a practical, useful document results

Substantial uncertainties -- specifically to include the rate of development of the Russian economy (GDP, future electricity demand and the availability/relative prices of natural gas, coal and other forms of energy) -- make evaluation of alternatives and the development of action plans complex For this reason, a small number of alternative scenarios will also require analysis, these will have to anticipate and provide the flexibility required to adapt to changing circumstances

In the course of the work, alternatives to be evaluated will include but not be limited to the following

- Upgrading or replacement of aging thermal power stations,
- Closure of least-safe nuclear power plants,
- Major safety upgrades of the least risky nuclear power plants,
- Completion of partly-built nuclear power plants, conversion of partly-built nuclear power plants to gas or coal (repowering), and development of new nuclear capacity,
- Measures for improvement of high-voltage transmission
- Measures for creating major improvements in Russian energy efficiency, thereby limiting future electricity demand growth,
- Increased natural gas use for power generation,

- A potential role for clean coal technologies,
- Potential for electric power exports and impacts on financing of power sector developments and domestic electric power supply/demand balances

The study will draw heavily upon existing Russian research, specifically to include "An Energy Strategy for Russia" (A A Makarov, principal researcher) Work also will be based upon and extend the analysis underlying the previously accomplished Government of Russia/World Bank/ IEA electricity options paper

Organization of the Study

The study will be organized into joint Russian/American Working Groups, and a Joint Steering Committee, responsible for high-level direction of the work, including approval of study objectives, scope, deliverables, and detailed work plans, in addition to regular review of project progress Tile Joint Steering Committee will include representatives of the following Russian organizations

- Ministry of Fuels and Energy
- Ministry of Atomic Energy
- Ministry of Economy Ministry of Foreign Economic Relations
- Ministry of Environmental Protection and Natural Resources
- State Atomic Energy Inspectorate (Gosatomnadzor)
- State Electric Power Company RAO EES Rossii
- State Nuclear Power Company RosEnergoAtom
- Russian Academy of Sciences
- Russian Agency for International Cooperation and Development, and
- Other interested agencies

It will include the following U S entities

- Agency for International Development (USAID)
- Department of State
- Department of Energy
- Nuclear Regulatory Commission, and
- Other interested agencies

Further intra-governmental discussions identified the U S Agency for International Development and the Russian State Electric Power Company RAO EES Rossii as the lead organizations in the work Both will work in close cooperation with the World Bank, the European Bank for Reconstruction and Development (EBRD), and other international financial institutions These terms of reference (TOR), prepared by a joint working group with input from a wide group of interested parties, represent the beginning of the joint study

Initial membership and leadership of the working groups were identified by the lead agencies (USAID and RAO EES ROSSII) in a meeting in Moscow, November 9-11, 1993, and the work plans below were developed

The five working groups are as follows

Working Group 1 -- Energy Efficiency To evaluate and recommend pricing policy reforms and other measures, including specific end-use technologies to encourage efficient use of energy in key sectors Focus will be on low-cost/no-cost energy efficiency improvement measures, as well as on the financing aspects of energy-saving measures

Working Group 2 -- Thermal Power Generation To address the needs for upgrading/replacement of aging thermal power plants Fuel availability, environmental impacts, and investments will be considered

Working Group 3 -- Nuclear Power Alternatives To evaluate and recommend, as required, closure of least safe nuclear plants, safety upgrades of selected nuclear power plants, the completion or repowering of partly-built nuclear plants, and the construction of new nuclear plants, including analysis of practical consequences of each

Working Group 4 -- Power Transmission and Dispatch To consider upgrades to the high-voltage transmission system and improved utilization of existing assets through improved system dispatch and power wheeling policies

Working Group 5 -- Energy Strategy Investments and Integration To perform the integrating function for the other working groups Working Group 5 will provide the consistent underlying assumptions (inter alia, fuel prices availability, and desired export earnings levels) for the other groups, will work interactively to bring together the results of other groups' work to develop integrated, time-phased action plans with investment and financing requirements, and proposals for potential financial mechanisms and terms of investment This Working Group also will develop assumptions and analyses outside the scope of the other Working Groups The group shall carry out various expert assessments of various options for the sector's development submitted by the Russian side to be presented in a format conventional for the western business community

The list of contributing and implementing organizations includes, in addition to the organizations represented on the Steering Committee, the following

- RCG/Hagler Bailly and subcontractors
- Burns and Roe Enterprises and subcontractors
- Institute for Energy Research, Russian Academy of Sciences
- EnergoSetProject
- Electric Power Institute
- TeploElectroProject
- Central Dispatch Center
- Russian Energy Saving Fund
- Other independent consultants as necessary, and Other U S agency participation as required for information policy coordination and project implementation

Project Schedule

The following schedule assumes that a document approved by both governments will be completed in June 1994 However, because of the magnitude of the work anticipated and the limited time, it is recognized that both Governments may jointly decide by April 1994 to treat the June 1994 report as an interim report for the G-7, with a final report due before the end of 1994

To render the process more efficient, at least some meetings of the Steering Committee could be held via Washington/Moscow teleconferencing

January 1994	Study approved by JCTC
December 1993	Meeting between Russian and American sides to review terms of reference and provide guidance on project objectives and focus
February 1994	Set up Steering Committee, update membership of joint Working Groups, and begin work
March 1994	Working Groups deliver preliminary results, tentative conclusions are drawn, June report structure and content are proposed

April 1, 1994	Steering Committee reviews project progress, tentative conclusions, proposed structure of final report Steering Committee decides whether to recommend treating the June report as interim or final report
May 1994	Draft final report completed and reviewed by Steering Committee In the event that a decision is taken in April 1994 to make this an interim report, the Steering Committee in May 1994 will propose the schedule, objectives, and contents of the final report, and will propose how it wishes to recommend that the interim report should be treated by the G-7
June 1994	Steering Committee approves report to be shared with G7
December 1994	If so required, Steering Committee approves final report

Working Group 3 Nuclear Power Alternatives

I Objectives and Responsibilities

A Should the decision be taken to shut down first generation reactors, analyze the economic and practical consequences of such a possible decision, especially an assessment of the costs directly associated with the decommissioning of operating nuclear power plants, but also the economic and social consequences to the nuclear work force

B Assess the consequences and costs of converting partly-built nuclear power plant construction sites that were never completed into power stations that use fossil fuels

C Determine the costs of utilizing partly-completed nuclear power plants to replace old reactor units, including safety-related upgrades necessary to achieve a level of safety comparable to the West, additional construction costs, plant operation and fuel costs, and impacts on energy infrastructure

D Take into account Russian plans for new nuclear generation, including new nuclear power plant designs adapted from current designs, and their anticipated costs

E Take into account Russian plans for upgrading existing nuclear power plants and their anticipated costs

F Take into account cost of continued operation of first generation VVER and all RBMK reactors to the end of their lifetimes with upgrades to standards acceptable to the West

II Specific Tasks and Schedule

February	Prepare detailed group work plan including proposed level of effort Review existing information, classifications, reports, plans, and assessments regarding nuclear generating capacity Develop an initial classification of existing power plants
February	Assess alternatives and their costs for completion of partly-built plants, new designs, and decommissioning
March	Deliver tentative results, including classification of existing, partly-built, and potential new capacity, with one or a few recommended action plans, including cost estimates and financing schedules
April	Finalize recommendations, action plans, and financing requirements
May	Modify analysis based on reviews of results and document the analysis

ANNEX 2 BASIC ASSUMPTIONS ON NUCLEAR FUEL PRICES

A2 1 MODEL OF THE NUCLEAR FUEL CYCLE

The assumed model of the nuclear cycle is shown below As shown, the fuel cycle consists of eight phases from uranium extraction through the final disposal of spent fuel This composition of the fuel cycle corresponds to the so-called open or once-through cycle when there is not fuel reprocessing and related activities Other possible fuel cycles (closed cycle with the use of reprocessed uranium and plutonium, thorium cycle) are less ready for practical implementation and therefore excluded from consideration in this study

The assumed durations of the phases as well as the model itself are taken from a recent study on the nuclear fuel cycle conducted by OECD and NEA [1]

Phase 1 Uranium Extraction
Assumed time before fuel loading = 2 0 Years phase duration 0 5 years

Phase 2 Conversion to UF_6
Assumed time before fuel loading = 1 0 years phase duration 0 5 years

Phase 3 Uranium Enrichment
Assumed time before fuel loading phase duration 0 5 years

Phase 4 Fuel Fabrication
Assumed time before fuel loading = 0 5 years phase duration 0 5 years

Phase 5 Burning Fuel in Reactor
Assumed time before fuel loading = 0 0 years phase duration 3 0 years

Phase 6 Temporary Fuel Storage On Site
Assumed time after loading = 3 0 years phase duration 5 0 years

Phase 7 Long Term Fuel Storage Off Site
Assumed time after fuel loading = 8 0 years, phase duration 35 0 years

Phase 8 Final Fuel Encapsulation and Disposal
Assumed time after fuel loading = 43 0 years, phase duration 0 5 years

A2 2 GENERAL ASSUMPTIONS FOR FUEL PRICE SCENARIOS

Three scenarios of the prices for nuclear fuel are suggested minimum price scenario, average price scenario and maximum price scenario The average price scenario should be part of the reference case in the integrated model The other two scenarios should be considered as sensitivity or change cases The basic assumptions common for all scenarios are as follows

- Due to the existence of large stocks of extracted uranium in various forms in Russia (low-enriched uranium, enrichment tails, high-enriched uranium, reprocessed uranium) price escalation for nuclear fuel over the whole period of the study need not be considered Thus, it is sufficient to determine the price for only one reference year of the study, e g , 1994
- The model of the fuel cycle is as shown above Thus, there are six components in the price of nuclear fuel 1) the cost of yellow cake (U_3O_8), 2) the cost of the conversion to UF_6, 3) the cost of the separative work unit (SWU), 4) the cost of fuel fabrication, 5) the cost of long-term fuel storage off-site and 6) the cost of the final encapsulation and disposal of nuclear fuel The costs of burning the fuel in the reactor and of the temporary storage on-site are traditionally related to the operation costs and are not included into the fuel price The costs incurred at different times during the nuclear fuel cycle should be levelised to the moment of placing the fabricated fuel into the reactor *
- All the prices are calculated on the assumption that the raw material is natural uranium with an assay of 0 71% in uranium-235
- The uranium-235 contents in the enrichment tails is assumed to be 0 3%
- The price of nuclear fuel is determined on a unit-by-unit basis depending on the enrichment of the

* The levelization of different time costs in this context means the levelization of all fuel cycle costs to the time of placing the fuel to the reactor Such a procedure is necessary for nuclear fuel to account for substantial time differences among various investments required However, this levelization is different from the cost levelization to be implemented within the integrated model of a power system The latter levelises all the costs to one selected time point, usually the beginning of the planning period There is not a contradiction between the two mentioned types of levelization, on the contrary, both are required for a fair representation of the system

fuel used

Concerning the latter three assumptions, one should note that they simplify the actual situation, because the existing variety of nuclear fuels is not taken into account However, at the moment there is not enough quantitative data for a formulation of a better assumption The collection of such data and formulation of relevant assumptions represents a separate and complex task

The specific assumptions for each scenario are given below in Section A2 4

A2 3 APPROACH TO CALCULATING THE FUEL COST

The set of prices taken in the mentioned OECD/NEA study [1] as the Reference Case is used here as the basis for the formulation of various fuel price scenarios These prices, in accordance with the assumed fuel cycle model are as shown below (in US dollars of 1991)

Phase 1 (Uranium Extraction)	**50$/KgU as U_{308}**
Phase 2 (Conversion to UF_6)	**8$/KgU as UF_6**
Phase 3 (Uranium Enrichment)	**110$/SWU**
Phase 4 (Fuel Fabrication)	**275$/KgU**
Phase 7 (Long-term Fuel Storage Off-site)	**340$/KgU**
Phase 8 (Final Fuel Encapsulation and Disposal)	**1100/KgU**

One important point must be underlined here All the given prices relate to the starting point of the corresponding phase in the nuclear fuel cycle In particular, the prices of long-term fuel storage and final fuel disposal are the costs of the whole phase levelised at the discount rate of 10% to the point of delivery to the fuel storage or fuel disposal site correspondingly (The 10% discount rate is taken in accordance with the assumptions of the integrated model) It means that all the prices relate to essentially different times To convert this set of data into the components of the price of fuel delivered to plant it is necessary to levelise all the costs to the point of fuel delivery to plant Such levelization at the discount rate of 10% gives us a set of actual reference data to be used as the basis for assigning fuel costs

Phase 1

50 $/kgU as U_3O_8 => $50 \times \exp(0\ 1\ \ 2\ 0\text{years}) = 50 \times 1\ 22 = 61$ $/kgU as U_3O_8

Phase 2

8 $/kgU as UF_6 => $8 \times \exp(0\ 1\ \ 1\ 5\text{years}) = 8 \times 1\ 16 = 9\ 3$ $/kgU as UF_6

Phase 3

110 \$/SWU => 110 × exp(0 1 1 0years) = 110 × 1 11 = 122 \$/SWU

Phase 4

275 \$/kgU => 275 × exp(0 1 0 5years) = 275 × 1 05 = 289 \$/kgU

Phase 7

340 \$/kgU => 340 × exp(-0 1 8 0years) = 340 × 0 449 = 153 \$/kgU

Phase 8

1100 \$/kgU => 1100 × exp(-0 1 43 0years) = 1100 × 0 014 = 15 \$/kgU

The given numbers form the basic set of data to be used for the formulation of different fuel price scenarios This basic set will be, however, transformed for every specific scenario in accordance with ~~the~~ specific assumptions ~~for a scenario~~ as discussed below

A2 4 FORMULATION OF FUEL PRICE SCENARIOS

As mentioned above, three scenarios of the prices for nuclear fuel are suggested minimum price scenario, average price scenario and maximum price scenario The average price scenario should be part of the reference case in the integrated model The other two scenarios should be considered as sensitivity or change cases The specific assumptions for these scenarios are as follows

Average (Reference Case) Price Scenario

Assumptions

- The costs of U_3O_8, conversion to UF_6 and SWU are as the prices at the world unrestricted market This market is served mainly by the CIS countries including Russia. The assumed costs are as given below [2]

18 \$/kgU as U_3O_8, 6 \$/kgU for conversion to UF_6 and 67 \$/SWU

- The cost of fuel fabrication is assumed to be half of the price in the reference set of data shown above, i e , 289/2 » 145 \$/kgU The coefficient of 0 5 is used here to reflect the differences between the Russian and world market conditions The value of the coefficient roughly corresponds to the general ratio between the US and Russian cost bases as found by WG #3 in its studies

- The same ratio of 0 5 is used for the costs of the long-term fuel storage and final disposal for the same reason

The resulting set of costs for the average price scenario is shown below

Phase 1 (Uranium Extraction).	**18 × 1 22 = 22 $/kgU as U_3O_8**
Phase 2 (Conversion to UF_6)	**6 × 1 16 = 7 $/kgU as UF_6**
Phase 3 (Uranium Enrichment)	**67 × 1 11 = 74 $/SWU**
Phase 4 (Fuel Fabrication)	**145 $/kgU**
Phase 7 (Long-term Fuel Storage off-Site)	**76 $/kgU**
Phase 8 (Final Fuel Encapsulation and Disposal)	**7 $/kgU**

Maximum (Sensitivity Case) Price Scenario

Assumption

- All costs are the prices characteristic for long-term contracts of major producers in the world market as assessed in [1], i e , these are prices of the Reference case in [1] as shown below

Phase 1 (Uranium Extraction)	**61 $/kgU as U_3O_8**
Phase 2 (Conversion to UF6)	**9 $/kgU as UF6**
Phase 3 (Uranium Enrichment)	**122 $/SWU**
Phase 4 (Fuel Fabrication)	**289 $/kgU**
Phase 7 (Long-term Fuel Storage off-Site)	**153 $/kgU**
Phase 8 (Final Fuel Encapsulation and Disposal)	**15 $/kgU**

Minimum (Sensitivity Case) Price Scenario

Assumptions

- The price of enriched uranium is assumed to be zero This reflects the fact that a very large stock of enriched uranium, including highly enriched uranium, exists in Russia. Although the level of enrichment of a portion of such stocks is less than required for reactor fuel, assuming a zero cost for enriched uranium remains a reasonable basis for establishing a least cost In this case, the cost of reactor fuel consists of two components fuel fabrication and the back-end component Strictly speaking, the cost of fuel storage in stocks should be present also, but it is a rather small component and for the purpose of this study one can be disregarded It should be remembered that this scenario is to represent an extreme case, most favorable for nuclear power and designed with the objective to investigate within the integrated model the marginal system impact of the cost of nuclear fuel In reality, such a case could occur only for a limited quantities for nuclear fuel

- The prices of fuel fabrication, long-term storage and final fuel disposal are assumed to be as in the average price scenario

The set of data for the minimum price scenario is shown below

Phase 4 (Fuel Fabrication)	**145 \$/kgU**
Phase 7 (Long-term Fuel Storage off-Site)	**76 \$/kgU**
Phase 8 (Final Fuel Encapsulation and Disposal)	**7 \$/kgU**

A2 5 EXAMPLE CALCULATIONS

Example for the Average Price Scenario

For VVER-1000 with the fuel enrichment of 4 4 wt% (9 98 kg of natural U and 6 04 SWU per 1 kg of enriched uranium) the price of enriched uranium will be

$$(22 + 7)\ \ 9\ 98 + 74\ \ 6\ 04 = 289 + 447 = 736\ \$/kgU$$

Taking into account fuel fabrication and the back-end of fuel cycle, the final price of nuclear fuel amounts to

$$736 + 145 + 76 + 7 = 964\ \$/kgU$$

At the average burnup of 40 MWd/kgU and net plant efficiency of 31 2% this is equivalent to the fuel component of the cost of electricity of

964 / 40 / 24 / 0 312 = 3 2 mills/kWh

Example for the Maximum Price Scenario

For the same VVER-1000 the price of enriched uranium will be

(61 + 9)   9 98 + 122   6 04 = 699 + 737 = 1436 $/kgU

Accordingly, the price of the nuclear fuel delivered to plant amounts to

1436 + 289 + 153 + 15 = 1893 $/kgU

At the average burnup of 40 MWd/kgU and net plant efficiency of 31 2% this is equivalent to the fuel component of the cost of electricity of

1893 / 40 / 24 / 0 312 = 6 3 mills/kWh

(One may notice that this number is close to typical numbers for US plants, see, e g , [3])

Example for the Minimum Price Scenario

For the same VVER-1000 the price ***of the nuclear fuel delivered to plant*** will be

145 + 76 + 7 = 228 $/kgU

At the average burnup of 40 MWd/kgU and net plant efficiency of 31 2% this is equivalent to the fuel component of the cost of electricity of

228 / 40 / 24 / 0 312 = 0 8 mills/kWh

The nuclear fuel costs on a unit-by-unit basis are given in Appendix I as part of the input data for the integrating models

A2 6 REFERENCES TO DATA SOURCES

1 The Economics of the Nuclear Fuel Cycle OECD (Organisation for Economic Co-

operation and Development) / NEA (Nuclear Energy Agency) Revised Final Draft NEA/EFC/DOC(93)1, June 1993

2 Nuclear Fuel A biweekly Report from the Editors of Nucleonics Week Vol 19, No 10-May 9, 1994

3 Projected Costs of Generating Electricity Update 1992 OECD (Organisation for Economic Co-operation and Development) / IEA (International Energy Agency) / NEA (Nuclear Energy Agency) 1993

ANNEX 3 SUMMARIES OF BCC AND O&M COST EVALUATION RESULTS

A3 1 INTRODUCTION

The Base Construction Costs (BCC) and Non Fuel Operating and Maintenance (O&M) Cost estimates developed for the JPNAS were prepared in accordance with the cost evaluation methodology discussed in Section 4 0 and 5 0 of this final report The BCC and O&M costs were estimated as a constant January 1, 1994 US dollars

The O&M costs are presented in terms of Fixed and Variable costs Fixed costs are those which are independent of the unit's output, such as staff salaries, and are given in dollars per kilowatt-year ($/kW-yr) Variable costs are those which vary with the unit's output, such as expendable supplies, and are given in mills/kilowatt-hour (mills/kWh)

A3 2 COST ESTIMATE RESULTS

For convenience of use, the BCC summary tables are divided into three separate parts as follows

Part A "Overnight" BCC in thousands of constant 1/1/94 US dollars, including direct and indirect costs with owner's and contingency costs added, in an data base major system/structure code of accounts

Part B The same costs as in Part A, but expressed as a percentage of the total "Overnight" BCC

Part C The same costs as in Part A, but expressed as dollars per gross kilowatts electric ($/gkWe)

While the summary overnight BCC may be found in Part A, cost drivers may be identified in Part B and the costs normalized to capacity may be reviewed in Part C Parts A and B also provide an activity (construction and decommissioning) duration for each of the options, while Part C provides a current year (1/1/94) present worth value for each of the options The RBMK project duration includes a 1 year shutdown for the jet condenser/confinement design and a 3 year shutdown for the full containment option (both include fuel channel replacement) The VVER project duration includes a 6 month shutdown for the jet condenser/confinement design and a 3 year shutdown for the full containment design

Separate estimates based on conditions that prevail in the US and on Russian conditions are provided Two different estimates for Russian conditions are provided, one based upon US to Russian conversion factors developed by the JPNAS, in these tables labeled "JPNAS", and one based upon US to Russian conversion factors developed by the Russian Energy Research Institute for use in the JEPAS, in these tables labeled "ERI/JEPAS"

The costs in the tables are presented as maximum and minimum estimates The maximum assessment for each option is the maximum cost of upgrade implementation among all units considered A similar definition is used for the minimum estimates Note that an "N/A" in the tables refers to "Not Applicable" Also note that columns for VVER-440 units include data for all VVER-440 models (V-230, V-213, and V-179)

"OVERNIGHT" BASE CONSTRUCTION COST ESTIMATE SUMMARY

(Continuation, Repowering, Completion/Upgrade, Upgrade, and New Generation

Table A3-1A Under U S Conditions on a Multi-Unit Basis

(In Thousands of Constant January 1, 1994 U S Dollars)

ENERGY ECONOMIC DATA BASE		OPTION 1 CONTINUATION								OPTION 3 REPOWERING	OPTION 4 COMPLETION/ UPGRADE	OPTION 5 UPGRADE OPERATING UNIT		OPTION 6 NEW GENERATION	
ACCT NO	ACCOUNT DESCRIPTION	WITH CONFINEMENT AND JET CONDENSER				WITH FULL CONTAINMENT									
		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		VVER 1000 1500 MWe	VVER 1000 1000 MWe	VVER-1000 1000 MWe		NF 500 635 MWe	
		HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW			HIGH	LOW	HIGH	LOW
21	STRUCTURES & IMPROVEMENTS	45 000	18 189	19 588	2 492	218 612	156 885	123 662	91 000	123 572	81 104	11 067	6 837	160 476	128 381
22	REACTOR PLANT EQUIPMENT	77 129	41 846	32 836	6 362	146 782	95 712	43 806	28 395	579 005	62 750	23 487	15 109	270 001	216 001
23	TURBINE PLANT EQUIPMENT			4 730	2 582			3 116	2 585	81 869	33 289	3 330	613	181 021	144 817
24	ELECTRIC PLANT EQUIPMENT	32 075		6 794	5 129	54 315	16 684	29 045	5 090	56 132	34 772	10 273	4 544	64 882	51 905
25	MISCELLANEOUS PLANT EQUIPT	577	433	4 766	619	2 520	1 890	5 118	619	43 566	17 212	5 035	2 061	42 960	34 368
26	MAIN COND HEAT REJECTION SYS			984				984			10 769			31 418	25 134
2	**TOTAL DIRECT COST**	**154 781**	**60 468**	**69 698**	**17,184**	**422,229**	**271,171**	**205,731**	**127,689**	**884,144**	**239,896**	**53,192**	**29,164**	**750,758**	**600,606**
91	CONSTRUCTION SERVICES	20 022	7 862	8 849	2 135	67 123	45 759	33 902	24 161	118 353	73 521	7 603	4 270	147 517	118 013
92	ENGINEERING & H/O SERVICES	3 785	1 504	13 674	13 418	15 413	14 499	42 604	36 173	19 591	93 023	20 661	15 077	40 300	32 240
93	FIELD SUPER & F/O SERVICES	15 152	5 895	7 560	1 875	57 552	40 331	33 440	23 484	51 745	57 149	6 934	3 906	88 652	70 921
99	SOCIAL ECONOMIC COST	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	**TOTAL INDIRECT COST**	**38,959**	**15,261**	**30,083**	**17,428**	**140,088**	**100,589**	**109 946**	**83,818**	**189 689**	**223,693**	**35 198**	**23,253**	**276,469**	**221,174**
2 + 9	**BASE CONSTRUCTION COST**	**193,740**	**75,729**	**99,781**	**34 612**	**562 317**	**371,760**	**315 677**	**211 507**	**1 073 833**	**463 589**	**88 390**	**52,417**	**1 027 227**	**821,780**
	CONTINGENCY + OWNER S COST	30 030	11 738	15 466	5 365	87 159	57 623	48 930	32 783	383 359	97 353	9 060	5 375	427 326	341 861
	BCC W/CONT + O C	**223 770**	**87,467**	**115,247**	**39,977**	**649,476**	**429,383**	**364,607**	**244,290**	**1,457,192**	**560,942**	**97,450**	**57,792**	**1,454,553**	**1,163,641**
	ACTIVITY DURATION (MONTHS)	**24**		**21**		**36**		**36**		**24**	**26**	**18**		**48**	

"OVERNIGHT" BASE CONSTRUCTION COST ESTIMATE SUMMARY

(Continuation, Repowering, Completion/Upgrade, Upgrade, and New Generation

Table A3-1B Under U S Conditions on a Multi-Unit Basis

(In Percentage of Constant January 1, 1994 Base Construction Costs)

ENERGY ECONOMIC DATA BASE		OPTION 1 CONTINUATION								OPTION 3 REPOWERING	OPTION 4 COMPLETION/ UPGRADE	OPTION 5 UPGRADE OPERATING UNIT		OPTION 6 NEW GENERATION	
ACCT NO	ACCOUNT DESCRIPTION	WITH CONFINEMENT AND JET CONDENSER				WITH FULL CONTAINMENT				VVER 1000 1500 MWe	VVER 1000 1000 MWe	VVER 1000 1000 MWe		NF 500 635 MWe	
		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe							
		HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW			HIGH	LOW	HIGH	LOW
21	STRUCTURES & IMPROVEMENTS	23 2%	24 0%	19 6%	7 2%	38 9%	42 2%	39 2%	43 0%	11 5%	17 5%	12 5%	13 0%	15 6%	15 6%
22	REACTOR PLANT EQUIPMENT	39 8%	55 3%	32 9%	18 4%	26 1%	25 7%	13 9%	13 4%	53 9%	13 5%	26 6%	28 8%	26 3%	26 3%
23	TURBINE PLANT EQUIPMENT			4 7%	7 5%			1 0%	1 2%	7 6%	7 2%	3 8%	1 2%	17 6%	17 6%
24	ELECTRIC PLANT EQUIPMENT	16 6%		6 8%	14 8%	9 7%	4 5%	9 2%	2 4%	5 2%	7 5%	11 6%	8 7%	6 3%	6 3%
25	MISCELLANEOUS PLANT EQUIPT	0 3%	0 5%	4 8%	1 8%	0 4%	0 5%	1 6%	0 3%	4 1%	3 7%	5 7%	4 0%	4 2%	4 2%
26	MAIN COND HEAT REJECTION SYS			1 0%				0 3%			2 3%			3 1%	3 1%
2	**TOTAL DIRECT COST**	**79 9%**	**79 8%**	**69 8%**	**49 7%**	**75 1%**	**72 9%**	**65 2%**	**60 3%**	**82 3%**	**51 7%**	**60 2%**	**55 7%**	**73 1%**	**73 1%**
91	CONSTRUCTION SERVICES	10 3%	10 4%	8 9%	6 2%	11 9%	12 3%	10 7%	11 4%	11 0%	15 9%	8 6%	8 1%	14 4%	14 4%
92	ENGINEERING & H/O SERVICES	2 0%	2 0%	13 7%	38 8%	2 7%	3 9%	13 5%	17 1%	1 8%	20 1%	23 4%	28 8%	3 9%	3 9%
93	FIELD SUPER & F/O SERVICES	7 8%	7 8%	7 8%	5 4%	10 2%	10 8%	10 6%	11 1%	4 8%	12 3%	7 8%	7 5%	8 6%	8 6%
99	SOCIAL ECONOMIC COST	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	**TOTAL INDIRECT COST**	**20 1%**	**20 2%**	**30 4%**	**50 4%**	**24 8%**	**27 0%**	**34 8%**	**39 6%**	**17 6%**	**48 3%**	**39 8%**	**44 4%**	**26 9%**	**26 9%**
2 + 9	**BASE CONSTRUCTION COST**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**
	CONTINGENCY + OWNER S COST	15 5%	15 5%	15 5%	15 5%	15 5%	15 5%	15 5%	15 5%	35 7%	21 0%	10 3%	10 3%	41 6%	41 6%
	BCC W/CONT + O C	**115 5%**	**115 5%**	**115 5%**	**115 5%**	**115 5%**	**115 5%**	**115 5%**	**115 5%**	**135 7%**	**121 0%**	**110 3%**	**110 3%**	**141 6%**	**141 6%**
	ACTIVITY DURATION (MONTHS)	24		21		36		36		24	26	18		48	

"OVERNIGHT" BASE CONSTRUCTION COST ESTIMATE SUMMARY

(Continuation, Repowering, Completion/Upgrade, Upgrade, and New Generation

Table A3-1C Under U S Conditions on a Multi-Unit Basis

(In Constant January 1, 1994 U S $/Gross kWe)

ENERGY ECONOMIC DATA BASE		OPTION 1 CONTINUATION								OPTION 3 REPOWERING	OPTION 4 COMPLETION/ UPGRADE	OPTION 5 UPGRADE OPERATING UNIT		OPTION 6 NEW GENERATION	
ACCT NO	ACCOUNT DESCRIPTION	WITH CONFINEMENT AND JET CONDENSER				WITH FULL CONTAINMENT				VVER 1000	VVER 1000	VVER 1000		NF 500	
		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		1500 MWe	1000 MWe	1000 MWe		635 MWe	
		HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW			HIGH	LOW	HIGH	LOW
21	STRUCTURES & IMPROVEMENTS	45	18	45	6	219	157	281	207	83	81	11	7	253	202
22	REACTOR PLANT EQUIPMENT	77	42	75	14	147	96	100	65	386	63	23	15	425	340
23	TURBINE PLANT EQUIPMENT			11	6			7	6	55	33	3	1	285	228
24	ELECTRIC PLANT EQUIPMENT	32		15	12	54	17	66	12	37	35	10	5	102	82
25	MISCELLANEOUS PLANT EQUIPT	1	0	11	1	3	2	12	1	29	17	5	2	68	54
26	MAIN COND HEAT REJECTION SYS			2				2			11			49	40
2	**TOTAL DIRECT COST**	**155**	**60**	**159**	**39**	**423**	**272**	**468**	**291**	**590**	**240**	**52**	**30**	**1,182**	**946**
91	CONSTRUCTION SERVICES	20	8	20	5	67	46	77	55	79	74	8	4	232	186
92	ENGINEERING & H/O SERVICES	4	2	31	30	15	14	97	82	13	93	21	15	63	51
93	FIELD SUPER & F/O SERVICES	15	6	17	4	58	40	76	53	35	57	7	4	140	112
99	SOCIAL ECONOMIC COST	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	**TOTAL INDIRECT COST**	**39**	**16**	**68**	**39**	**140**	**100**	**250**	**190**	**127**	**224**	**36**	**23**	**435**	**349**
2 + 9	**BASE CONSTRUCTION COST**	**194**	**76**	**227**	**78**	**563**	**372**	**718**	**481**	**717**	**464**	**88**	**53**	**1,617**	**1,295**
	CONTINGENCY + OWNER S COST	30	12	35	12	87	56	111	75	255	97	9	5	673	538
	BCC W/CONT + O C	**224**	**88**	**262**	**90**	**650**	**428**	**829**	**556**	**972**	**561**	**97**	**58**	**2 290**	**1,833**
	PRESENT WORTH	**158**	**28**	**188**	**64**	**402**	**87**	**513**	**394**	**627**	**446**	**63**	**37**	**1,291**	**896**

"OVERNIGHT" BASE CONSTRUCTION COST ESTIMATE SUMMARY

(Continuation, Repowering, Completion/Upgrade, Upgrade, and New Generation

Table A3-2A Under Russian Conditions on a Multi-Unit Basis

(In Thousands of Constant January 1, 1994 U S Dollars)

JPNAS

ENERGY ECONOMIC DATA BASE		OPTION 1 CONTINUATION								OPTION 3 REPOWERING	OPTION 4 COMPLETION/ UPGRADE	OPTION 5 UPGRADE OPERATING UNIT		OPTION 6 NEW GENERATION	
		WITH CONFINEMENT AND JET CONDENSER				WITH FULL CONTAINMENT				VVER 1000	VVER 1000	VVER 1000		NF 500	
ACCT NO	ACCOUNT DESCRIPTION	RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		1500 MWe	1000 MWe	1000 MWe		635 MWe	
		HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW			HIGH	LOW	HIGH	LOW
21	STRUCTURES & IMPROVEMENTS	20 442	8 620	9 034	1 123	95 188	68 341	53 132	38 070	62 624	31 331	4 647	2 858	72 072	57 658
22	REACTOR PLANT EQUIPMENT	46 642	25 883	20 558	3 960	85 400	54 606	25 517	15 731	324 444	31 780	13 146	8 391	172 676	138 141
23	TURBINE PLANT EQUIPMENT			2 690	1 344			1 790	1 346	52 094	13 370	1 796	407	111 771	89 417
24	ELECTRIC PLANT EQUIPMENT	21 665		4 572	3 083	36 621	11 217	17 029	3 059	28 927	15 571	6 539	2 786	34 948	27 958
25	MISCELLANEOUS PLANT EQUIPT	316	237	1 801	245	1 016	762	1 985	245	20 035	6 735	2 002	794	21 320	17 056
26	MAIN COND HEAT REJECTION SYS			387				387			3 266			17 314	13 851
2	**TOTAL DIRECT COST**	**89 065**	**34,740**	**39,042**	**9,755**	**218 225**	**134 926**	**99 840**	**58 451**	**488,124**	**102,053**	**28,130**	**15,236**	**430 101**	**344,081**
91	CONSTRUCTION SERVICES	12 865	5 054	5 738	1 382	43 804	29 979	22 359	15 937	67 947	41 145	4 971	2 796	79 711	63 769
92	ENGINEERING & H/O SERVICES	1 419	564	5 128	5 032	5 780	5 437	15 976	13 565	7 347	34 884	7 748	5 654	15 112	12 090
93	FIELD SUPER & I/O SERVICES	5 479	2 125	2 733	670	20 969	14 713	12 203	8 582	20 273	22 672	2 512	1 417	34 352	27 482
99	SOCIAL ECONOMIC COST	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	**TOTAL INDIRECT COST**	**19 763**	**7,743**	**13,599**	**7,084**	**70,553**	**50 129**	**50 538**	**38 084**	**95 567**	**98,701**	**15,231**	**9,867**	**129 175**	**103 341**
2 + 9	**BASE CONSTRUCTION COST**	**108,828**	**42 483**	**52 641**	**16 839**	**288 778**	**185,055**	**150 378**	**96,535**	**583,691**	**200 754**	**43 361**	**25 103**	**559,276**	**447,422**
	CONTINGENCY + OWNER S COST	16 868	6 585	8 159	2 610	44 761	28 684	23 309	14 963	208 378	42 158	4 445	2 573	232 660	186 128
	BCC W/CONT + O C	**125 696**	**49,068**	**60 800**	**19,449**	**333,539**	**213,739**	**173,687**	**111,498**	**792 069**	**242,912**	**47,806**	**27,676**	**791,936**	**633,550**
	ACTIVITY DURATION (MONTHS)	24		21		36		36		24	26	18		48	

"OVERNIGHT" BASE CONSTRUCTION COST ESTIMATE SUMMARY

(Continuation, Repowering, Completion/Upgrade, Upgrade, and New Generation

Table A3-2B Under Russian Conditions on a Multi-Unit Basis

(As Percentage of January 1, 1994 Base Construction Costs) **JPNAS**

ENERGY ECONOMIC DATA BASE		OPTION 1 CONTINUATION								OPTION 3 REPOWERING	OPTION 4 COMPLETION/ UPGRADE	OPTION 5 UPGRADE OPERATING UNIT		OPTION 6 NEW GENERATION	
		WITH CONFINEMENT AND JET CONDENSER				WITH FULL CONTAINMENT									
ACCT NO	ACCOUNT DESCRIPTION	RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		VVER 1000 1500 MWe	VVER 1000 1000 MWe	VVER 1000 1000 MWe		NF 500 635 MWe	
		HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW			HIGH	LOW	HIGH	LOW
21	STRUCTURES & IMPROVEMENTS	18 8%	20 3%	17 2%	6 7%	33 0%	36 9%	35 3%	39 4%	10 7%	15 6%	10 7%	11 4%	12 9%	12 9%
22	REACTOR PLANT EQUIPMENT	42 9%	60 9%	39 1%	23 5%	29 6%	29 5%	17 0%	16 3%	55 6%	15 8%	30 3%	33 4%	30 9%	30 9%
23	TURBINE PLANT EQUIPMENT			5 1%	8 0%			1 2%	1 4%	8 9%	6 7%	4 1%	1 6%	20 0%	20 0%
24	ELECTRIC PLANT EQUIPMENT	19 9%		8 7%	18 3%	12 7%	6 1%	11 3%	3 2%	5 0%	7 8%	15 1%	11 1%	6 2%	6 2%
25	MISCELLANEOUS PLANT EQUIPT	0 3%	0 6%	3 4%	1 5%	0 4%	0 4%	1 3%	0 3%	3 4%	3 4%	4 6%	3 2%	3 8%	3 8%
26	MAIN COND HEAT REJECTION SYS			0 7%				0 3%			1 6%			3 1%	3 1%
2	**TOTAL DIRECT COST**	**81 9%**	**81 8%**	**74 2%**	**58 0%**	**75 7%**	**72 9%**	**66 4%**	**60 6%**	**83 6%**	**50 9%**	**64 8%**	**60 7%**	**76 9%**	**76 9%**
91	CONSTRUCTION SERVICES	11 8%	11 9%	10 9%	8 2%	15 2%	16 2%	14 9%	16 5%	11 6%	20 5%	11 5%	11 1%	14 3%	14 3%
92	ENGINEERING & H/O SERVICES	1 3%	1 3%	9 7%	29 9%	2 0%	2 9%	10 6%	14 1%	1 3%	17 4%	17 9%	22 5%	2 7%	2 7%
93	FIELD SUPER & F/O SERVICES	5 0%	5 0%	5 2%	4 0%	7 3%	8 0%	8 1%	8 9%	3 5%	11 3%	5 8%	5 6%	6 1%	6 1%
99	SOCIAL ECONOMIC COST	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	**TOTAL INDIRECT COST**	**18 1%**	**18 2%**	**25 8%**	**42 1%**	**24 5%**	**27 1%**	**33 6%**	**39 5%**	**16 4%**	**49 2%**	**35 2%**	**39 2%**	**23 1%**	**23 1%**
2 + 9	**BASE CONSTRUCTION COST**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**
	CONTINGENCY + OWNER S COST	15 5%	15 5%	15 5%	15 5%	15 5%	15 5%	15 5%	15 5%	35 7%	21 0%	10 3%	10 3%	41 6%	41 6%
	BCC W/CONT + O C	**115 5%**	**115 5%**	**115 5%**	**115 5%**	**115 5%**	**115 5%**	**115 5%**	**115 5%**	**135 7%**	**121 0%**	**110 3%**	**110 3%**	**141 6%**	**141 6%**
	ACTIVITY DURATION (MONTHS)	**24**		**21**		**36**		**36**		**24**	**26**	**18**		**48**	

"OVERNIGHT" BASE CONSTRUCTION COST ESTIMATE SUMMARY
(Continuation, Repowering, Completion/Upgrade, Upgrade, and New Generation
Table A3-2C Under Russian Conditions on a Multi-Unit Basis
(In Constant January 1, 1994 U S $/Gross kWe) JPNAS

ENERGY ECONOMIC DATA BASE		*OPTION 1 CONTINUATION*								OPTION 3 REPOWERING	OPTION 4 COMPLETION/ UPGRADE	OPTION 5 UPGRADE OPERATING UNIT		OPTION 6 NEW GENERATION	
		WITH CONFINEMENT AND JET CONDENSER				WITH FULL CONTAINMENT				VVER 1000	VVER 1000	VVER 1000		NF 500	
ACCT NO	ACCOUNT DESCRIPTION	RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		1500 MWe	1000 MWe	1000 MWe		635 MWe	
		HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW			HIGH	LOW	HIGH	LOW
21	STRUCTURES & IMPROVEMENTS	20	9	21	3	95	68	121	87	42	31	5	3	113	91
22	REACTOR PLANT EQUIPMENT	47	26	47	9	85	55	58	36	216	32	13	8	272	218
23	TURBINE PLANT EQUIPMENT			6	3			4	3	35	13	2	0	176	141
24	ELECTRIC PLANT EQUIPMENT	22		10	7	37	11	39	7	19	16	7	3	55	44
25	MISCELLANEOUS PLANT EQUIPT	0	0	4	1	1	1	5	1	13	7	2	1	34	27
26	MAIN COND HEAT REJECTION SYS			1				1			3			27	22
2	**TOTAL DIRECT COST**	**89**	**35**	**89**	**23**	**218**	**135**	**228**	**134**	**325**	**102**	**29**	**15**	**677**	**543**
91	CONSTRUCTION SERVICES	13	5	13	3	44	30	51	36	45	41	5	3	126	100
92	ENGINEERING & H/O SERVICES	1	1	12	11	6	5	36	31	5	35	8	6	24	19
93	FIELD SUPER & F/O SERVICES	5	2	6	2	21	15	28	20	13	23	3	1	54	43
99	SOCIAL ECONOMIC COST	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	**TOTAL INDIRECT COST**	**19**	**8**	**31**	**16**	**71**	**50**	**115**	**87**	**63**	**99**	**16**	**10**	**204**	**162**
2 + 9	**BASE CONSTRUCTION COST**	**108**	**43**	**120**	**39**	**289**	**185**	**343**	**221**	**389**	**201**	**45**	**25**	**881**	**705**
	CONTINGENCY + OWNER S COST	17	7	19	6	45	29	53	34	139	42	4	3	405	293
	BCC W/CONT + O C	**125**	**50**	**139**	**45**	**334**	**214**	**396**	**255**	**527**	**243**	**49**	**28**	**1,286**	**998**
	PRESENT WORTH	**89**	**16**	**99**	**31**	**206**	**43**	**244**	**180**	**341**	**193**	**31**	**18**	**567**	**489**

"OVERNIGHT" BASE CONSTRUCTION COST ESTIMATE SUMMARY

(Continuation, Repowering, Completion/Upgrade, Upgrade, and New Generation

Table A3-3A Under Russian Conditions on a Multi-Unit Basis

(In Thousands of Constant January 1, 1994 U S Dollars) ERI-JEAS

ENERGY ECONOMIC DATA BASE		OPTION 1 CONTINUATION								OPTION 3 REPOWERING	OPTION 4 COMPLETION/ UPGRADE	OPTION 5 UPGRADE OPERATING UNIT		OPTION 6 NEW GENERATION	
		WITH CONFINEMENT AND JET CONDENSER				WITH FULL CONTAINMENT				VVER 1000	VVER 1000	VVER-1000		NF 500	
ACCT NO	ACCOUNT DESCRIPTION	RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		1500 MWe	1000 MWe	1000 MWe		635 MWe	
		HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW			HIGH	LOW	HIGH	LOW
21	STRUCTURES & IMPROVEMENTS	16 599	7 249	6 385	740	67 446	48 283	37 095	26 432	53 776	22 513	3 494	2 147	56 518	45 214
22	REACTOR PLANT EQUIPMENT	32 515	18 164	14 362	2 761	59 296	37 810	17 598	10 730	224 212	22 320	9 202	5 886	122 744	98 195
23	TURBINE PLANT EQUIPMENT			1 847	983			1 227	984	36 694	8 667	1 320	289	78 484	62 787
24	ELECTRIC PLANT EQUIPMENT	15 443		3 247	2 139	26 053	802	12 445	2 122	21 564	10 937	4 604	1 946	24 704	19 764
25	MISCELLANEOUS PLANT EQUIPT	242	182	1 097	179	720	540	1 220	179	13 302	4 291	1 232	481	14 594	11 675
26	MAIN COND HEAT REJECTION SYS			281				281			1 842			12 010	9 608
2	**TOTAL DIRECT COST**	**64,799**	**25,595**	**27,219**	**6 802**	**153,515**	**87 435**	**69,866**	**40 447**	**349,548**	**70 570**	**19,852**	**10 749**	**309,054**	**247 243**
91	CONSTRUCTION SERVICES	10 879	4 271	4 784	1 153	36 485	24 875	18 360	13 134	51 974	31 837	4 114	2 311	62 640	50 112
92	ENGINEERING & H/O SERVICES	379	150	1 367	1 342	1 541	1 450	4 260	3 617	1 959	9 302	2 066	1 508	4 030	3 224
93	FIELD SUPER & F/O SERVICES	1 533	603	774	202	5 809	4 074	3 398	2 392	6 778	8 756	705	397	12 481	9 985
99	SOCIAL ECONOMIC COST	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	**TOTAL INDIRECT COST**	**12,791**	**5,024**	**6,925**	**2,697**	**43 835**	**30,399**	**26,018**	**19,143**	**60,711**	**49,895**	**6,885**	**4,216**	**79,151**	**63 321**
2 + 9	**BASE CONSTRUCTION COST**	**77,590**	**30 619**	**34,144**	**9,499**	**197,350**	**117,834**	**95 884**	**59,590**	**410,259**	**120,465**	**26 737**	**14,965**	**388,205**	**310,564**
	CONTINGENCY + OWNER S COST	12 027	4 746	5 293	1 472	30 589	18 264	14 882	9 236	146 462	25 298	2 741	1 534	160 662	129 195
	BCC W/CONT + O C	**89 617**	**35,365**	**39 437**	**10,971**	**227,939**	**136,098**	**110,766**	**68 826**	**556,721**	**145,763**	**29,478**	**16,499**	**548,867**	**439,759**
	ACTIVITY DURATION (MONTHS)	**24**		**21**		**36**		**36**		**24**	**26**	**18**		**48**	

"OVERNIGHT" BASE CONSTRUCTION COST ESTIMATE SUMMARY

(Continuation, Repowering, Completion/Upgrade, Upgrade, and New Generation

Table A3-3B Under Russian Conditions on a Multi-Unit Basis

(In Percentage of January 1, 1994 Base Construction Costs) ERI-JEAS

ENERGY ECONOMIC DATA BASE		OPTION 1 CONTINUATION								OPTION 3 REPOW-ERING	OPTION 4 COMPLE TION/ UPGRADE	OPTION 5 UPGRADE OPERATING UNIT		OPTION 6 NEW GENERATION	
		WITH CONFINEMENT AND JET CONDENSER				WITH FULL CONTAINMENT									
ACCT NO	ACCOUNT DESCRIPTION	RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		VVER 1000 1500 MWe	VVER 1000 1000 MWe	VVER 1000 1000 MWe		NF 500 635 MWe	
		HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW			HIGH	LOW	HIGH	LOW
21	STRUCTURES & IMPROVEMENTS	21 4%	23 7%	18 7%	7 8%	34 2%	41 0%	38 7%	44 4%	13 1%	18 7%	13 1%	14 3%	14 6%	14 6%
22	REACTOR PLANT EQUIPMENT	41 9%	59 3%	42 1%	29 1%	30 0%	32 1%	18 4%	18 0%	54 7%	18 5%	34 4%	39 3%	31 6%	31 6%
23	TURBINE PLANT EQUIPMENT			5 4%	10 3%			1 3%	1 7%	8 9%	7 2%	4 9%	1 9%	20 2%	20 2%
24	ELECTRIC PLANT EQUIPMENT	19 9%		9 5%	22 5%	13 2%	0 7%	13 0%	3 6%	5 3%	9 1%	17 2%	13 0%	6 4%	6 4%
25	MISCELLANEOUS PLANT EQUIPT	0 3%	0 6%	3 2%	1 9%	0 4%	0 5%	1 3%	0 3%	3 2%	3 6%	4 0%	3 2%	3 8%	3 8%
26	MAIN COND HEAT REJECTION SYS			0 8%				0 3%			1 5%			3 1%	3 1%
2	**TOTAL DIRECT COST**	**83 5%**	**83 6%**	**79 7%**	**71 6%**	**77 8%**	**74 3%**	**73 0%**	**68 0%**	**85 2%**	**58 6%**	**73 6%**	**71 7%**	**79 7%**	**79 7%**
91	CONSTRUCTION SERVICES	14 0%	14 0%	14 0%	12 1%	18 5%	21 0%	19 1%	22 0%	12 7%	28 6%	15 4%	15 4%	16 1%	16 1%
92	ENGINEERING & H/O SERVICES	0 5%	0 5%	4 0%	14 1%	0 8%	1 2%	4 4%	6 1%	0 5%	7 7%	7 7%	10 1%	1 0%	1 0%
93	FIELD SUPER & F/O SERVICES	2 0%	2 0%	2 3%	2 1%	2 9%	3 5%	3 5%	4 0%	1 7%	7 3%	2 8%	2 7%	3 2%	3 2%
99	SOCIAL ECONOMIC COST	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	**TOTAL INDIRECT COST**	**16 5%**	**16 5%**	**20 3%**	**28 3%**	**22 2%**	**25 7%**	**27 0%**	**32 1%**	**14 9%**	**43 6%**	**25 9%**	**28 2%**	**20 3%**	**20 3%**
2 + 9	**BASE CONSTRUCTION COST**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**
	CONTINGENCY + OWNER S COST	15 5%	15 5%	15 5%	15 5%	15 5%	15 5%	15 5%	15 5%	35 7%	21 0%	10 3%	10 3%	41 6%	41 6%
	BCC W/CONT + O C	**115 5%**	**115 5%**	**115 5%**	**115 5%**	**115 5%**	**115 5%**	**115 5%**	**115 5%**	**135 7%**	**121 0%**	**110 3%**	**110 3%**	**141 6%**	**141 6%**
	ACTIVITY DURATION (MONTHS)	24		21		36		36		24	26	18		48	

"OVERNIGHT" BASE CONSTRUCTION COST ESTIMATE SUMMARY

(Continuation, Repowering, Completion/Upgrade, Upgrade, and New Generation

Table A3-3C Under Russian Conditions on a Multi-Unit Basis

(In Constant January 1, 1994 U S $/Gross kWe) ERI-JAES

ENERGY ECONOMIC DATA BASE		OPTION 1 CONTINUATION								OPTION 3 REPOWERING	OPTION 4 COMPLETION/ UPGRADE	OPTION 5 UPGRADE OPERATING UNIT		OPTION 6 NEW GENERATION	
ACCT NO	ACCOUNT DESCRIPTION	WITH CONFINEMENT AND JET CONDENSER				WITH FULL CONTAINMENT				VVER 1000	VVER 1000	VVER 1000		NF 500	
		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		1500 MWe	1000 MWe	1000 MWe		635 Mwe	
		HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW			HIGH	LOW	HIGH	LOW
21	STRUCTURES & IMPROVEMENTS	17	7	15	2	67	48	84	60	36	23	3	2	89	71
22	REACTOR PLANT EQUIPMENT	33	18	33	6	59	38	40	24	149	22	9	6	193	155
23	TURBINE PLANT EQUIPMENT			4	2			3	2	25	9	1	0	124	99
24	ELECTRIC PLANT EQUIPMENT	15		7	5	26	1	28	5	15	11	5	2	39	31
25	MISCELLANEOUS PLANT EQUIPT	0	0	2	0	1	1	3	0	9	4	1	0	23	18
26	MAIN COND HEAT REJECTION SYS			1				1			2			19	15
2	**TOTAL DIRECT COST**	**65**	**25**	**62**	**15**	**153**	**88**	**159**	**91**	**233**	**71**	**19**	**10**	**487**	**389**
91	CONSTRUCTION SERVICES	11	4	11	3	36	25	42	30	35	32	4	2	99	79
92	ENGINEERING & H/O SERVICES	0	0	3	3	2	1	10	8	1	9	2	2	6	5
93	FIELD SUPER & F/O SERVICES	2	1	2	0	6	4	8	5	5	9	1	0	20	16
99	SOCIAL ECONOMIC COST	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	TOTAL INDIRECT COST	13	5	16	6	44	30	60	43	41	50	7	4	125	100
2 + 9	BASE CONSTRUCTION COST	78	30	78	21	197	118	219	134	274	121	26	14	612	489
	CONTINGENCY + OWNER S COST	12	5	12	3	31	18	34	21	97	25	3	2	254	203
	BCC W/CONT + O C	90	35	90	24	228	136	253	155	371	146	29	16	866	692
	PRESENT WORTH	63	11	64	18	141	28	156	111	240	116	19	11	415	339

"OVERNIGHT" BASE CONSTRUCTION COST ESTIMATE SUMMARY

(Option-2 Decommissioning)

Table A3-4A Under U S Conditions on a Multi-Unit Basis

(In Thousands of Constant January 1, 1994 U S Dollars)

ENERGY ECONOMIC DATA BASE		PLANNED DECOMMISSIONING								EARLY DECOMMISSIONING							
		RUSSIAN APPROACH				U S APPROACH				RUSSIAN APPROACH				U S APPROACH			
ACC No	ACCOUNT DESCRIPTION	RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe	
		HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW
21	STRUCTURES & IMPROVEMENTS	7 115		7 115		7 115		7 115		7 115		7 115		7 115		7 115	
22	REACTOR PLANT EQUIPMENT	38 437		18 985		38 437		18 985		38 437		18 985		38 437		18 985	
23	TURBINE PLANT EQUIPMENT																
24	ELECTRIC PLANT EQUIPMENT																
25	MISCELLANEOUS PLANT EQUIPT																
26	MAIN COND HEAT REJECTION SYS																
2	**TOTAL DIRECT COST**	**45,552**	**0**	**26,100**	**0**	**45 552**	**0**	**26,100**	**0**	**45,552**	**0**	**26,100**	**0**	**45,552**	**0**	**26,100**	**0**
91	CONSTRUCTION SERVICES	440 787	435 391	217 455	213 783	130 119	124 724	118 653	114 982	440 509	435 114	217 446	213 774	130 119	124 724	118 653	114 982
92	ENGINEERING & H/O SERVICES	1 288		952		1 288		952		1 288		952		1 288		952	
93	FIELD SUPER & F/O SERVICES	489 370	483 813	230 391	226 296	82 009	76 452	61 117	57 025	488 676	483 119	230 196	226 104	82 009	76 452	61 117	57 025
99	SOCIAL ECONOMIC COST	112 182	112 182	81 965	81 965	112 182	112 182	81 965	81 965	135 777	135 777	88 900	88 900	138 566	138 566	90 116	90 116
9	**TOTAL INDIRECT COST**	**1 043,627**	**1 031 3 86**	**530 763**	**522 044**	**325 598**	**313,358**	**262,687**	**253,972**	**1 066 250**	**1 054 010**	**537 494**	**528,778**	**351,982**	**339 742**	**270,838**	**262,123**
2 + 9	**BASE CONSTRUCTION COST**	**1,089,179**	**1 031 3 86**	**556,863**	**522 044**	**371,150**	**313,358**	**288,787**	**253 972**	**1 111 802**	**1,054 010**	**563 594**	**528,778**	**397,534**	**339,742**	**296,938**	**262,123**
	CONTINGENCY	163 377	154 708	83 529	78 307	55 673	47 004	43 318	38 096	166 770	158 101	84 539	79 317	59 630	50 961	44 541	39 316
	BCC W/CONTINGENCY	**1,252 556**	**1 186 0 94**	**640,392**	**600 351**	**426 823**	**360,362**	**332,105**	**292 068**	**1 278 572**	**1,212,111**	**648 133**	**608 095**	**457,164**	**390,703**	**341 479**	**301,439**
	ACTIVITY DURATION (MONTHS)	**516**		**516**		**144**		**120**		**480**		**480**		**144**		**120**	

"OVERNIGHT" BASE CONSTRUCTION COST ESTIMATE SUMMARY

(Option-2 Decommissioning)

Table A3-4B Under U S Conditions on a Multi-Unit Basis

(In Percentage of January 1, 1994 Base Construction Costs)

ENERGY ECONOMIC DATA BASE		PLANNED DECOMMISSIONING								EARLY DECOMMISSIONING							
ACC NO	ACCOUNT DESCRIPTION	RUSSIAN APPROACH				U S APPROACH				RUSSIAN APPROACH				U S APPROACH			
		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe	
		HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW
21	STRUCTURES & IMPROVEMENTS	0 7%		1 3%		1 9%		2 5%		0 6%		1 3%		1 8%		2 4%	
22	REACTOR PLANT EQUIPMENT	3 5%		3 4%		10 4%		6 6%		3 5%		3 4%		9 7%		6 4%	
23	TURBINE PLANT EQUIPMENT																
24	ELECTRIC PLANT EQUIPMENT																
25	MISCELLANEOUS PLANT EQUIPT																
26	MAIN COND HEAT REJECTION SYS																
2	**TOTAL DIRECT COST**	**4 2%**	**0 0%**	**4 7%**	**0 0%**	**12 3%**	**0 0%**	**9 1%**	**0 0%**	**4 1%**	**0 0%**	**4 7%**	**0 0%**	**11 5%**	**0 0%**	**8 8%**	**0 0%**
91	CONSTRUCTION SERVICES	40 5%	42 2%	39 1%	41 0%	35 1%	39 8%	41 1%	45 3%	39 6%	41 3%	38 6%	40 4%	32 7%	36 7%	40 0%	43 9%
92	ENGINEERING & H/O SERVICES	0 1%		0 2%		0 3%		0 3%		0 1%		0 2%		0 3%		0 3%	
93	FIELD SUPER & F/O SERVICES	44 9%	46 9%	41 4%	43 3%	22 1%	24 4%	21 2%	22 5%	44 0%	45 8%	40 8%	42 8%	20 6%	22 5%	20 6%	21 8%
99	SOCIAL ECONOMIC COST	10 3%	10 9%	14 7%	15 7%	30 2%	35 8%	28 4%	32 3%	12 2%	12 9%	15 8%	16 8%	34 9%	40 8%	30 3%	34 4%
9	**TOTAL INDIRECT COST**	**95 8%**	**100 0%**	**95 4%**	**100 0%**	**87 7%**	**100 0%**	**91 0%**	**100 1%**	**95 9%**	**100 0%**	**95 4%**	**100 0%**	**88 5%**	**100 0%**	**91 2%**	**100 1%**
2 + 9	**BASE CONSTRUCTION COST**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**
	CONTINGENCY	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%
	BCC W/CONTINGENCY	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**
	ACTIVITY DURATION (MONTHS)	**516**		**516**		**120**		**95**		**480**		**480**		**144**		**120**	

“OVERNIGHT” BASE CONSTRUCTION COST ESTIMATE SUMMARY

(Option-2 Decommissioning)

Table A3-5A Under U S Conditions on a Multi-Unit Basis

(In Thousands of Constant January 1, 1994 U S Dollars)

JPNAS

ENERGY ECONOMIC DATA BASE		PLANNED DECOMMISSIONING								EARLY DECOMMISSIONING							
		RUSSIAN APPROACH				U S APPROACH				RUSSIAN APPROACH				U S APPROACH			
		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe	
ACC NO	ACCOUNT DESCRIPTION	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW
21	STRUCTURES & IMPROVEMENTS	3 043		3 043		3 043		3 043		3 043		3 043		3 043		3 043	
22	REACTOR PLANT EQUIPMENT	25 202		12 447		25 202		12 447		25 202		12 447		25 202		12 447	
23	TURBINE PLANT EQUIPMENT																
24	ELECTRIC PLANT EQUIPMENT																
25	MISCELLANEOUS PLANT EQUIPT																
26	MAIN COND HEAT REJECTION SYS																
2	**TOTAL DIRECT COST**	**28,245**	**0**	**15 490**	**0**	**28 245**	**0**	**15,490**	**0**	**28,245**	**0**	**15 490**	**0**	**28,245**	**0**	**15 490**	**0**
91	CONSTRUCTION SERVICES	90 924	87 710	65 141	62 956	42 990	39 777	42 924	40 739	90 844	87 631	65 129	62 944	42 990	39 777	42 924	40 739
92	ENGINEERING & H/O SERVICES	483		357		483		357		483		357		483		357	
93	FIELD SUPER & F/O SERVICES	50 884	48 381	24 510	22 630	31 173	28 669	23 264	21 384	50 815	48 312	24 491	22 610	31 173	28 669	23 264	21 384
99	SOCIAL ECONOMIC COST	11 218	11 218	8 196	8 196	11 218	11 218	8 196	8 196	13 578	13 578	8 890	8 890	13 857	13 857	9 012	9 012
9	**TOTAL INDIRECT COST**	**153 509**	**147,309**	**98,204**	**93,782**	**85,864**	**79,664**	**74,741**	**70,319**	**155,720**	**149 521**	**98,867**	**94,444**	**88 503**	**82,303**	**75 557**	**71,135**
2 + 9	**BASE CONSTRUCTION COST**	**181,754**	**147,309**	**113,694**	**93,782**	**114,109**	**79,664**	**90,231**	**70,319**	**183 965**	**149 521**	**114 357**	**94,444**	**116,748**	**82,303**	**91,047**	**71,135**
	CONTINGENCY	27 263	22 096	17 054	14 067	17 116	11 950	13 535	10 546	27 595	22 428	17 154	14 167	17 512	12 345	13 657	10 670
	BCC W/CONTINGENCY	**209,017**	**169 405**	**130,748**	**107,849**	**131,225**	**91,614**	**103 766**	**80 865**	**211 560**	**171,949**	**131,511**	**108 611**	**134,260**	**94,648**	**104,704**	**81,805**
	ACTIVITY DURATION (MONTHS)	**516**		**516**		**144**		**120**		**480**		**480**		**144**		**120**	

"OVERNIGHT" BASE CONSTRUCTION COST ESTIMATE SUMMARY

(Option-2 Decommissioning)

Table A3-5B Under U S Conditions on a Multi-Unit Basis

(In Percentage of January 1, 1994 Base Construction Costs)

JPNAS

ENERGY ECONOMIC DATA BASE		PLANNED DECOMMISSIONING								EARLY DECOMMISSIONING							
		RUSSIAN APPROACH				U S APPROACH				RUSSIAN APPROACH				U S APPROACH			
ACC NO	ACCOUNT DESCRIPTION	RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe	
		HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW
21	STRUCTURES & IMPROVEMENTS	1 7%		2 7%		2 7%		3 4%		1 7%		2 7%		2 6%		3 3%	
22	REACTOR PLANT EQUIPMENT	13 9%		10 9%		22 1%		13 8%		13 7%		10 9%		21 6%		13 7%	
23	TURBINE PLANT EQUIPMENT																
24	ELECTRIC PLANT EQUIPMENT																
25	MISCELLANEOUS PLANT EQUIPT																
26	MAIN COND HEAT REJECTION SYS																
2	**TOTAL DIRECT COST**	**15 6%**	**0 0%**	**13 6%**	**0 0%**	**24 8%**	**0 0%**	**17 2%**	**0 0%**	**15 4%**	**0 0%**	**13 6%**	**0 0%**	**24 2%**	**0 0%**	**17 0%**	**0 0%**
91	CONSTRUCTION SERVICES	50 0%	59 5%	57 3%	67 1%	37 7%	49 9%	47 6%	57 9%	49 4%	58 6%	57 0%	66 6%	36 6%	48 3%	47 1%	57 3%
92	ENGINEERING & H/O SERVICES	0 3%		0 3%		0 4%		0 4%		0 3%		0 3%		0 4%		0 4%	
93	FIELD SUPER & F/O SERVICES	28 0%	32 8%	21 6%	24 1%	27 3%	36 0%	25 8%	30 4%	27 6%	32 3%	21 4%	23 9%	26 7%	34 8%	25 6%	30 1%
99	SOCIAL ECONOMIC COST	6 2%	7 6%	7 2%	8 7%	9 8%	14 1%	9 1%	11 7%	7 4%	9 1%	7 8%	9 4%	11 9%	16 8%	9 9%	12 7%
9	**TOTAL INDIRECT COST**	**84 5%**	**99 9%**	**86 4%**	**99 9%**	**75 2%**	**100 0%**	**82 9%**	**100 0%**	**84 7%**	**100 0%**	**86 5%**	**99 9%**	**75 6%**	**99 9%**	**83 0%**	**100 1%**
2 + 9	**BASE CONSTRUCTION COST**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**
	CONTINGENCY	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%
	BCC W/CONTINGENCY	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**
	ACTIVITY DURATION (MONTHS)	**516**		**516**		**120**		**95**		**480**		**480**		**144**		**120**	

"OVERNIGHT" BASE CONSTRUCTION COST ESTIMATE SUMMARY

(Option-2 Decommissioning)

Table A3-5C Under U S Conditions on a Multi-Unit Basis

(In Constant January 1, 1994 U S $/Gross kWe)

JPNAS

ENERGY ECONOMIC DATA BASE		PLANNED DECOMMISSIONING								EARLY DECOMMISSIONING							
ACC NO	ACCOUNT DESCRIPTION	RUSSIAN APPROACH				U S APPROACH				RUSSIAN APPROACH				U S APPROACH			
		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe	
		HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW
21	STRUCTURES & IMPROVEMENTS	3		7		3		7		3		7		3		7	
22	REACTOR PLANT EQUIPMENT	25		28		25		28		25		28		25		28	
23	TURBINE PLANT EQUIPMENT																
24	ELECTRIC PLANT EQUIPMENT																
25	MISCELLANEOUS PLANT EQUIPT																
26	MAIN COND HEAT REJECTION SYS																
2	**TOTAL DIRECT COST**	**28**	**0**	**35**	**0**	**28**	**0**	**35**	**0**	**28**	**0**	**35**	**0**	**28**	**0**	**35**	**0**
91	CONSTRUCTION SERVICES	91	88	148	143	43	40	98	93	91	88	148	143	43	40	98	93
92	ENGINEERING & H/O SERVICES	0		1		0		1		0		1		0		1	
93	FIELD SUPER & F/O SERVICES	51	48	56	51	31	29	53	49	51	48	56	51	31	29	53	49
99	SOCIAL ECONOMIC COST	11	11	19	19	11	11	19	19	14	14	20	20	14	14	20	20
9	**TOTAL INDIRECT COST**	**153**	**147**	**224**	**213**	**85**	**80**	**171**	**161**	**156**	**150**	**225**	**214**	**88**	**83**	**172**	**162**
2 + 9	**BASE CONSTRUCTION COST**	***181***	**147**	**259**	***213***	***113***	**80**	***206***	***161***	***184***	**150**	**260**	**214**	**116**	**83**	**207**	**162**
	CONTINGENCY	27	22	39	32	17	12	31	24	28	22	39	32	18	12	31	24
	BCC W/CONTINGENCY	**208**	**169**	**298**	**245**	**130**	**92**	**237**	**185**	**212**	**172**	**299**	**246**	**134**	**95**	**238**	**186**
	PRESENT WORTH	**22 0**	**1 8**	**26 9**	**4 1**	**17 2**	**1 1**	**26 7**	**3 6**	**31 2**	**2 6**	**39 4**	**5 8**	**27 8**	**1 8**	**41 6**	**5 5**

"OVERNIGHT" BASE CONSTRUCTION COST ESTIMATE SUMMARY

(Option-2 Decommissioning)

Table A3-6A Under U S Conditions on a Multi-Unit Basis

(In Thousands of Constant January 1, 1994 U S Dollars) **ERI-JEAS**

ENERGY ECONOMIC DATA BASE		PLANNED DECOMMISSIONING								EARLY DECOMMISSIONING							
		RUSSIAN APPROACH				U S APPROACH				RUSSIAN APPROACH				U S APPROACH			
ACC NO	ACCOUNT DESCRIPTION	RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK-1000 1000 MWe		VVER 440 440 MWe	
		HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW
21	STRUCTURES & IMPROVEMENTS	2 280		2 280		2 280		2 280		2 280		2 280		2 280		2 280	
22	REACTOR PLANT EQUIPMENT	18 008		8 800		18 008		8 800		18 008		8 800		18 008		8 800	
23	TURBINE PLANT EQUIPMENT																
24	ELECTRIC PLANT EQUIPMENT																
25	MISCELLANEOUS PLANT EQUIPT																
26	MAIN COND HEAT REJECTION SYS																
2	**TOTAL DIRECT COST**	20 288	0	11 080	0	20 288	0	11 080	0	20 288	0	11 080	0	20 288	0	11 080	0
91	CONSTRUCTION SERVICES	90 391	87 710	64 754	62 956	26 614	23 934	29 288	27 490	90 311	87 631	64 742	62 944	26 614	23 934	29 288	27 490
92	ENGINEERING & H/O SERVICES	129		95		129		95		129		95		129		95	
93	FIELD SUPER & F/O SERVICES	49 897	48 381	23 807	22 630	9 161	7 645	6 880	5 702	49 828	48 312	23 788	22 610	9 161	7 645	6 880	5 702
99	SOCIAL ECONOMIC COST	11 218	11 218	8 196	8 196	11 218	11 218	8 196	8 196	13 578	13 578	8 890	8 890	13 857	13 857	9 012	9 012
9	**TOTAL INDIRECT COST**	151 635	147 309	96 852	93 782	47 122	42 797	44 459	41 388	153 846	149 521	97 515	94 444	49 761	45 436	45 275	42 204
2 + 9	**BASE CONSTRUCTION COST**	171 923	147 309	107 932	93 782	67 410	42 797	55 539	41 388	174 134	149 521	108 595	94 444	70 049	45 436	56 355	42 204
	CONTINGENCY	25 788	22 096	16 190	14 067	10 111	6 420	8 331	6 206	26 120	22 426	16 289	14 167	10 507	6 815	8 453	6 331
	BCC W/CONTINGENCY	197 711	169 405	124 122	107 849	77 521	49 217	63 870	47 594	200 254	171 947	124 884	108 611	80 556	52 251	64 808	48 535
	ACTIVITY DURATION (MONTHS)	516		516		144		120		480		480		144		120	

“OVERNIGHT” BASE CONSTRUCTION COST ESTIMATE SUMMARY

(Option-2 Decommissioning)

Table A3-6B Under U.S. Conditions on a Multi-Unit Basis

(In Percentage of January 1, 1994 Base Construction Costs)

ERI-JEAS

ENERGY ECONOMIC DATA BASE		PLANNED DECOMMISSIONING								EARLY DECOMMISSIONING							
		RUSSIAN APPROACH				U S APPROACH				RUSSIAN APPROACH				U S APPROACH			
ACC NO	ACCOUNT DESCRIPTION	RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK-1000 1000 MWe		VVER 440 440 MWe	
		HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW
21	STRUCTURES & IMPROVEMENTS	1 3%		2 1%		0 4%		4 1%		1 3%		2 1%		3 3%		4 0%	
22	REACTOR PLANT EQUIPMENT	10 5%		8 2%		26 7%		15 8%		10 3%		8 1%		25 7%		15 6%	
23	TURBINE PLANT EQUIPMENT																
24	ELECTRIC PLANT EQUIPMENT																
25	MISCELLANEOUS PLANT EQUIPT																
26	MAIN COND HEAT REJECTION SYS																
2	**TOTAL DIRECT COST**	**11 8%**	**0 0%**	**10 3%**	**0 0%**	**27 1%**	**0 0%**	**19 9%**	**0 0%**	**11 6%**	**0 0%**	**10 2%**	**0 0%**	**29 0%**	**0 0%**	**19 6%**	**0 0%**
91	CONSTRUCTION SERVICES	52 6%	59 5%	60 0%	67 1%	39 5%	55 9%	52 7%	66 4%	51 9%	58 6%	59 6%	66 6%	38 0%	52 7%	52 0%	65 1%
92	ENGINEERING & H/O SERVICES	0 1%		0 1%		0 2%		0 2%		0 1%		0 1%		2%		0 2%	
93	29ELD SUPER & F/O SERVICES	29 0%	32 8%	22 1%	24 1%	13 6%	17 9%	12 4%	13 8%	28 6%	32 3%	21 9%	23 9%	13 1%	16 8%	12 2%	13 5%
99	SOCIAL ECONOMIC COST	6 5%	7 6%	7 6%	8 7%	16 6%	26 2%	14 8%	19 8%	7 8%	9 1%	8 2%	9 4%	19 8%	30 5%	16 0%	21 4%
9	**TOTAL INDIRECT COST**	**88 2%**	**99 9%**	**89 8%**	**99 9%**	**69 9%**	**100 0%**	**80 1%**	**100 0%**	**88 4%**	**100 0%**	**89 8%**	**99 9%**	**71 1%**	**100 0%**	**80 4%**	**100 0%**
2 + 9	**BASE CONSTRUCTION COST**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**	**100 0%**
	CONTINGENCY	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%	15 0%
	BCC W/CONTINGENCY	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**	**115 0%**
	ACTIVITY DURATION (MONTHS)	**516**		**516**		**120**		**95**		**480**		**480**		**144**		**120**	

"OVERNIGHT" BASE CONSTRUCTION COST ESTIMATE SUMMARY

(Option-2 Decommissioning)

Table A3-6C Under U S Conditions on a Multi-Unit Basis

(In Constant January 1, 1994 U S $/Gross kWe)

ERI-JEAS

ENERGY ECONOMIC DATA BASE		PLANNED DECOMMISSIONING								EARLY DECOMMISSIONING							
		RUSSIAN APPROACH				U S APPROACH				RUSSIAN APPROACH				U S APPROACH			
		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe		RBMK 1000 1000 MWe		VVER 440 440 MWe	
ACC NO	ACCOUNT DESCRIPTION	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW
21	STRUCTURES & IMPROVEMENTS	2		5		2		5		2		5		2		5	
22	REACTOR PLANT EQUIPMENT	18		20		18		20		18		20		18		20	
23	TURBINE PLANT EQUIPMENT																
24	ELECTRIC PLANT EQUIPMENT																
25	MISCELLANEOUS PLANT EQUIPT																
26	MAIN COND HEAT REJECTION SYS																
2	**TOTAL DIRECT COST**	**20**	**0**	**25**	**0**	**20**	**0**	**25**	**0**	**20**	**0**	**25**	**0**	**20**	**0**	**25**	**0**
91	CONSTRUCTION SERVICES	90	88	147	143	27	24	67	62	90	88	147	143	27	24	67	62
92	ENGINEERING & H/O SERVICES	0		0		0		0		0		0		0		0	
93	FIELD SUPER & F/O SERVICES	50	48	54	51	9	8	16	13	50	48	54	51	9	8	16	13
99	SOCIAL ECONOMIC COST	11	11	19	19	11	11	19	19	14	14	20	20	14	14	20	20
9	**TOTAL INDIRECT COST**	**151**	**147**	**220**	**213**	**47**	**43**	**102**	**94**	**154**	**150**	**221**	**214**	**50**	**46**	**103**	**95**
2 + 9	**BASE CONSTRUCTION COST**	**171**	**147**	**245**	**213**	**67**	**43**	**127**	**94**	**174**	**150**	**246**	**214**	**70**	**46**	**128**	**95**
	CONTINGENCY	26	22	37	32	10	6	19	14	26	22	37	32	11	7	19	14
	BCC W/CONTINGENCY	**197**	**169**	**282**	**245**	**77**	**49**	**146**	**108**	**200**	**172**	**283**	**246**	**81**	**53**	**147**	**109**
	PRESENT WORTH	**20 8**	**1 8**	**27 4**	**4 1**	**10 2**	**0 6**	**16 4**	**2 1**	**29 5**	**2 6**	**37 5**	**5 8**	**16 7**	**1 1**	**25 7**	**3 4**

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FIXED AND VARIABLE NON-FUEL OPERATING AND MAINTENANCE COST ESTIMATE SUMMARY

Table A3-7 Under U S Conditions on a Total Plant Basis
(In January 1, 1994 U S Dollars)

NON FUEL O & M COSTS	CONTINUATION				CONVERSION	COMPLETION/ UPGRADE	UPGRADE OPERATING UNIT		NEW GENERATION
	RBMK 1000 1000 MWe		VVER 440 440 MWe		VVER 1000 1000 MWe	VVER 1000 1000 MWe	VVER 1000 1000 MWe		NP 500 635 MWe
	HIGH	LOW	HIGH	LOW			HIGH	LOW	
FIXED O & M ($/kW yr)	164	147	170	141	31	149	225	149	77
VARIABLE O & M (mills/KWh)	0 7	0 6	1 0	0 8	2 4	0 9	1 3	0 9	0 4

FIXED AND VARIABLE NON-FUEL OPERATING AND MAINTENANCE COST ESTIMATE SUMMARY

Table A3-8 Under Russian Conditions on a Total Plant Basis

(In January 1, 1994 U S Dollars)

JPNAS

NON FUEL O & M COSTS	CONTINUATION				CONVERSION	COMPLETION/ UPGRADE	UPGRADE OPERATING UNIT		NEW GENERATIO N
	RBMK 1000 1000 MWe		VVER 440 440 MWe		VVER 1000 1000 MWe	VVER 1000 1000 MWe	VVER 1000 1000 MWe		NP 500 635 MWe
	HIGH	LOW	HIGH	LOW			HIGH	LOW	
FIXED O & M ($/kW - yr)	43	39	52	44	10	49	62	49	25
VARIABLE O & M (mills/KWh)	0 5	0 5	0 8	0 7	1 8	0 7	0 9	0 7	0 3

FIXED AND VARIABLE NON-FUEL OPERATING AND MAINTENANCE COST ESTIMATE SUMMARY

Table A3-9 Under Russian Conditions on a Total Plant Basis

(In January 1, 1994 U S Dollars)

ERI-JEAS

NON FUEL O & M COSTS	CONTINUATION				CONVERSION	COMPLETION/ UPGRADE	UPGRADE OPERATING UNIT		NEW GENERATION
	RBMK 1000 1000 MWe		VVER 440 440 MWe		VVER 1000 1000 MWe	VVER 1000 1000 MWe	VVER 1000 1000 MWe		NP 500 635 MWe
	HIGH	LOW	HIGH	LOW			HIGH	LOW	
FIXED O & M ($/kW yr)	32	30	47	35	10	38	47	38	19
VARIABLE O & M (mills/KWh)	0 5	0 5	0 8	0 7	3 0	0 7	0 9	0 7	0 3

Table A3-10 Additional Assessment of the Costs and Completion Schedules of NPP Units
(In Thousands of Constant January 1, 1994 U S Dollars)
Under Russian Conditions Using the ERI-JEAS Conversion Factors

NO	UNIT	REACTOR TYPE	BASE CONSTRUCTION COSTS					OTHER COSTS		TOTAL COSTS
			DIRECT COSTS				INDIRECT COSTS	OWNER's COSTS	CONTINGENCY	
			EQUIPMENT	LABOR	MATERIALS	TOTAL				
1	**Balakovo - 5**	VVER-1000	161 1	19 3	64 3	244 7	115 2	43 2	43 2	446 3
2	**Balakovo - 6**	VVER-1000	196 1	21 3	72 3	289 7	141 0	60 3	51 7	542 7
3	**Rostov - 1**	VVER-1000	16 1	9 3	7 3	32 7	32 3	6 5	6 5	78 0
4	**Kursk - 5**	RBMK-1000	19 2	15 3	35 2	79 7	92 9	19 0	17 3	208 8

COMPLETION DISBURSEMENT SCHEDULE

UNIT	DISBURSEMENTS, % OF TOTAL						
	1995	1996	1997	1998	1999	2000	2001
Balakovo - 5	10	25	25	25	15		
Balakovo - 6	10	15	20	25	20	10	
Rostov-1	80	20					
Kursk - 5	20	30	30	20			

*Completion status of Balakovo - 5 and Balakovo - 6 is as of 1993